Very Fast Chilling of Beef

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Introduction

In order to discourage microbial growth carcasses should be cooled as quickly as possible post-mortem (Lawrie, 1979). The European Un requirements are set out in the 1964 directive (64/433/EC) that "fresh meat intended for intra-community trade must be chilled immedia after the post-mortem inspection and kept at a constant temperature not more than +7 °C for carcasses and cuts and +3 °C for offal". In eff the meat in the deepest part of the carcass must be below 7 °C before leaving the factory. The rate of chilling is not specified, except to that the chilling regime must be begun "immediately after the post-mortem inspection". Meat factory practice is to try to chill meat carcas to the required temperature in approximately 18 hours. As a hot carcass loses heat to the refrigerated air surface moisture is also lost w resultant carcass weight loss of up to 2% (Gigiel, 1996). These losses are an order of magnitude higher than energy costs and are estimated Gigiel at between 2 and 4 pence per kg. This is about 20 times the cost of the energy consumed in the refrigeration process (Gigiel Collett, 1989). If weight loss is to be kept to a minimum surface temperature must be brought down quickly and rapid chilling must employed in the early stages of carcass refrigeration (Bailey, 1972; Cutting, 1972; James and Bailey, 1989). Attempts to achieve increas throughput, reduced microbial growth and lower weight loss has led to the development of fast chilling procedures, which are perform without concern for subsequent meat quality. The main obstacle to the adoption of rapid chilling is that if the meat temperature falls be 10°C in 10 hours toughening due to cold shortening results (Bendall, 1972). He states that *Cold -shortening sets in during the chilling of b if the temperature has fallen below 11 °C before the pH has fallen below 6.2. The severity of cold shortening is highly pH-dependant, be much greater at pH 6.8 (i.e. exceptionally rapid chilling) than at 6.2 (i.e. at an easily acceptable rate of chilling).* This rule implies t particularly slow glycolysing muscle (as is the case in beef) will be vulnerable to cold shortening. To elude cold shortening and tenderne decrease the muscle must be set in rigor mortis before it is chilled below 10 °C (Davey et al., 1976). The industry's problem is therefore prevent cold shortening while chilling fast enough to minimise weight loss and bacterial growth.

Some authors have found that rapidly chilling whole carcasses resulted in nothing more than cold toughened meat (Lawrie, 1979; Lock 1993). Very Fast Chilling (VFC), defined as the attainment of 0°C in 4 hours, as a chilling method has recently been suggested as a via alternative to conventional chilling without any detriment to meat quality (Bowling *et al.*, 1987; Sheridan, 1990; Jaime *et al.*, 1992; White *al.*, 1996).

The aim of the present study is two fold; firstly to investigate claims in the literature that the Very Fast Chilling of beef produces beef tender as slow chilled beef, and, secondly, to investigate the temperature requirements of Very Fast Chilling.

Materials and Methods

The experimental work was carried out in the experimental abbatoir at the National Food Centre. A chill room was modified so that cold was blown downwards through a polythene tunnel of 1.3m diameter in which a carcass sample or muscle (M. longissimus dorsi - LD) co be suspended. Rotating vane anemometers were used to measure air velocity.

Chilling regimes

The following two stage chilling regimes were chosen:- Very Fast Chilling, Slow (conventional) Chilling, and two intermediate Fast Chill with a Latin Square design applied to each. For each regime, Stage 2 (conditioning) used air at 0°C, 0.2m/s for the balance of 48 hours

Chilling Regime	Stage 1		
	Time	Temp.	Velocity
VFC – Very Fast Chilling	4 h	-30°C	2 m/s
SC – Slow Chilling	24 h	12°C	0 m/s
FC1 – Fast Chill 1	4 h	-10°C	0.2 m/s
FC2 – Fast Chill 2	4 h	-2°C	1.5 m/s

Tenderness evaluation was carried out according to the method of Boccard al (1981). After tempering the meat samples in a cold water bath approximately 4 °C) for 4-5 hours 2 steaks (2 cm in thickness and roughly g in weight) from each sample were weighed (for cook loss evaluation) cooked in unsealed vac-pack bags to an internal temperature of 70 °C water bath operating at 72 °C. From each steak 7 x 1.25 cm cores w obtained, with the long axis parallel to the muscle fibre direction. Bef sampling aging of samples at 4°C was carried for periods of up to 4 week Shear force measurements were made on an Instron Universal Testi machine, model 4464 (Instron, UK) fitted with a Warner-Bratzler head. The maximum force (N) to shear each core was recorded.

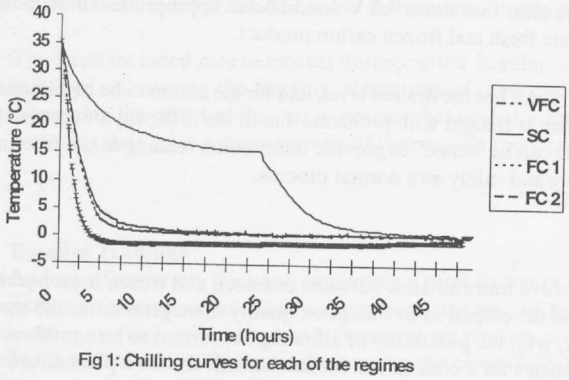

Fig 1: Chilling curves for each of the regimes

Results: *Chilling:* The cooling curves for the various chilling regimes shown in figure 1. These values were averaged over 20 animals for VFC SC and over 8 animals for FC1 and FC2. The VFC regime caused a rapid po mortem temperature fall in the first stage by using an ambient temperature 30°C for 4 hours. A temperature gradient of approximately 2 or 3 degrees fro the surface to the centre was evident in the first 4 hours of chilling and th centre temperature of the muscle achieved 0°C after 4 hours of chilling. Th surface temperature by this time had reached -2.2°C. Surface freezing d occur to a depth of 1 cm. Slow chilling SC allowed compliance with Bendall 10/10 rule of thumb, whereby the pH decreased below 6.2 before the muscle temperature reached 11°C thus avoiding cold shortening. After 4 hours chilling the centre temperature was 23.8 °C. Both FC options were below 5 within 10 h.

Tenderness Evaluation

Warner-Bratzler shear force is an objective, mechanical means of measuring the toughness / tenderness of meat. The influence of chilling regime tenderness of beef m. longissimus dorsi is shown in Fig 2. Results show that the shear force decreased during ageing for all chilling regimes There was a significant difference found between regimes after 2 days of ageing but over time this difference between VFC and SC becam non-significant with no significant differences between them after 14 days of aging. The two FC regimes, however, showed an unacceptable level of toughness at every measurement time. Values below about 70N are acceptable. Differences in pH became significant with aging.

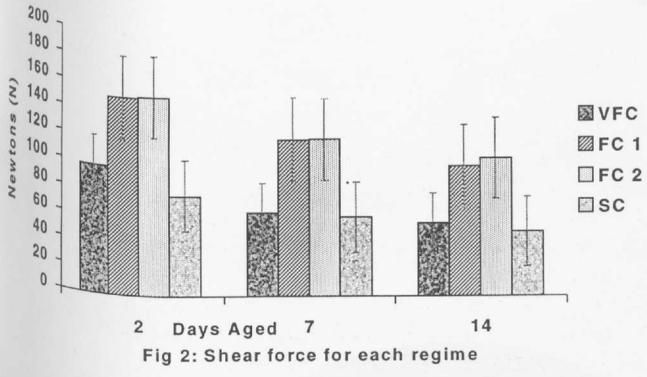

Fig 2: Shear force for each regime

Discussion

The results from the present study show that it was possible to produce tender meat from beef m. longissimus dorsi using the very fast chilling regime and aging the meat for 7 days. Very Fast Chilling (VFC) produced tender meat after 7 days ageing by chilling striploins for 4 hours at -30°C, at an air speed of 2 m/s. The tenderness observed was similar to that found in Slow Chilled (SC) samples after 7 days, which had been chilled firstly in ambient boning hall air for 24 hours and then at 0°C for a further 24 hours. This is in contrast to Bendalls "10/10 rule" which implies that very tough loins due to cold shortening should have been produced by chilling at very fast rates. Most research would indicate that meat chilled below 10°C in less than 10 hours results in unreversible cold toughening (Bendall, 1972). These authors found that muscles cooled in less than 10 hours under 11°C before the pH fell through 6.2 resulted in cold shortened meat. The present study seems to call this theory into question.

There is a growing body of evidence in the literature to suggest that rapid cooling may result in tender meat (Bendall, 1972; Bowling *et al.*, 1987; Sheridan, 1990; Jaime *et al.*, 1992). These authors achieved rates of temperature decline rapid enough to produce tender meat at approximately 7 days post-mortem. All of the above studies including the present had one stipulation. At approximately 5 hours post-mortem 0°C was achieved in the centre of the muscle examined. This may be the regulating factor in attaining tender meat from very fast chilling. All authors, including the present study, did find that intense toughening had occurred in rapidly cooled samples aged for a shorter period. Values in the current study were found as high as 130 Newtons after 2 days of ageing.

The shortening found in VFC samples at 2 days post-mortem is a direct result of the intense cold that the meat samples were subjected to. The M. longissimus dorsi was chosen in this study as it is the most rapidly frozen of the commercially important muscles and is therefore prone to toughening. The cold shock produced by the VFC regime caused the muscle fibres to contract resulting in the intense toughening found at 2 days post-mortem. This is in agreement with Locker (1993) who found that beef *sternomandibularis* muscle exhibited maximum shortening at 0°C.

Between 2 and 7 days post-mortem however an extreme tenderisation process had occurred in the VFC samples compared to SC samples. The shear force values had fallen from approximately 100 Newtons to 65 Newtons. This would be rated tender by a sensory panel. This tenderisation was more intense than the slow chilled samples which only decreased roughly 10 Newtons in both positions along the muscle. The mechanism for this reversal in cold toughened beef due to ageing has still not been developed. A number of theories have been volunteered.

Jamie *et al* (1992) found that exised pre-rigor lamb striploin brought to 0°C in 3 to 4 hours showed a tenderness maxima. To explain their results the authors suggested that shock chilling to 0°C releases extra Ca^{2+} from the sarcoplasmic reticulum. This Ca^{2+} which is known to activate the action of proteolytic enzymes (calpains) which cause an intense tenderisation capable of overcoming the toughness caused by cold shortening. The slightly higher pH which was found in the present study early post-mortem would help to further stimulate proteolysis. The initial increase in Ca^{2+} would promote the contraction of muscle by provoking shortening. If the action of the proteases were sufficiently fast and widespread the effect of contraction might be to pull apart sections of the muscle, exposing more protein chains to proteolytic attack and perhaps enhancing tenderness. Contraction would be continuous along a muscle length in order to increase toughness. In contrast, a small number of breaks created by proteolysis could produce an increase in tenderness out of all proportion to their number. A chain is only as strong as it's weakest link. The presence of cracks and breaks in the cytoskeletal structure therefore, would focus strain lines when stress is applied and thus increase the likelihood of fractures. Very little fracturing would be needed to produce a marked tenderising, a single broken sacromere in every thousand would rupture the fibre at 2 mm intervals.

A second theory that may account for the effect of Very Fast Chilling is skeletal restraint derived from surface freezing. Surface freezing was found on all VFC samples. This was due to the rapid temperature decline in VFC samples resulting in temperatures of -2°C being achieved for approximately 40 hours (figure 3.1 (a) and (b)). Surface freezing occurred to a depth of approximately 1 cm. This was reflected in the difficulty in obtaining the 4 and 5 hour pH measurements. Surface freezing may provide a restraining effect similar to that of bone attachments.

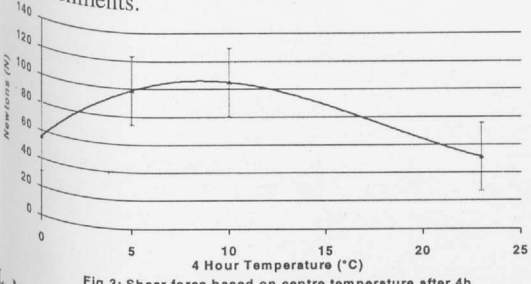

Fig 3: Shear force based on centre temperature after 4h

By having a frozen "crust" the muscle fibres would be fixed in place and unable to shorten. The extra restraints imposed by this surface hardening may be all that is required to overcome cold shortening. Unpublished work carried out in this laboratory has shown that VFC muscle, attained through a brine, which has not developed a crust did result in toughened meat (White *et al.*, 1996). The authors used a pre-cooled brine immersion to attain 0°C in 5 hours post-mortem but with no surface freezing. This technique yielded extremely tough meat.

References: Bailey, C. (1972) *Meat Chilling – Why and How* pp. 13.1-13.11
Bendall, J. R. (1972). *Meat Chilling - Why And How?* pp.3.1-3.6. Langford. Meat Research Institute.
Boccard, R., Buchter, L., Casteels, M., Cosentino, E., Dransfield, E., Hood, D. E., Joseph, R. L., MacDougall, D. B., Rhodes, D. N., Shon,I ., Tinbergen, B. J. and Touraille, C. (1981) *Livestock Production Science* (8), 385
Bowling, R. A., Dutson, T. R., Smith, G. C. and Savell, J. W. (1987). *Meat Science* (21) 67-72.
Cutting, C. L. (1972) *Meat Chilling – Why and How* pp. 18.1-18.3
Davet, C. L., Gilbert, C. K. V. and Carse, W. A. (1976) *New Zealand J. Agric. Res.* (19), 13-18
Gigiel, A. J. (1996). (Unpublished work).
Gigiel, A. J. and Collett, P. (1989). *Journal of Food Engineering* (10) 255-273.
Jaime, I., Beltrán, J. A., Ceña, P., López-Lorenzo, P. and Roncales, P. (1992). *Meat Science* (32) 357-366.
James, S. J. and Bailey, C. (1989) *Int. J. Refrig.* (12), 42-49
Lawrie, R. A. (1979). *Meat Science*, 3rd edn. pp.200-237. Oxford. Pergamon Press Inc.
Locker, R. H. (1993). pp.1-40. Westport, Connecticut. AVI publishing Company, Inc.
Sheridan, J. J. (1990). *Meat Science* (28) 31-50.
White, C. D., Troy, D. and McKenna, B. M. (1996). (Unpublished work).

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