

New Zealand Society of Animal Production online archive

This paper is from the New Zealand Society for Animal Production online archive. NZSAP holds a regular annual conference in June or July each year for the presentation of technical and applied topics in animal production. NZSAP plays an important role as a forum fostering research in all areas of animal production including production systems, nutrition, meat science, animal welfare, wool science, animal breeding and genetics.

An invitation is extended to all those involved in the field of animal production to apply for membership of the New Zealand Society of Animal Production at our website www.nzsap.org.nz

[View All Proceedings](#)

[Next Conference](#)

[Join NZSAP](#)

The New Zealand Society of Animal Production in publishing the conference proceedings is engaged in disseminating information, not rendering professional advice or services. The views expressed herein do not necessarily represent the views of the New Zealand Society of Animal Production and the New Zealand Society of Animal Production expressly disclaims any form of liability with respect to anything done or omitted to be done in reliance upon the contents of these proceedings.

This work is licensed under a [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](http://creativecommons.org/licenses/by-nc-nd/4.0/).



You are free to:

Share— copy and redistribute the material in any medium or format

Under the following terms:

Attribution — You must give [appropriate credit](#), provide a link to the license, and [indicate if changes were made](#). You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

NonCommercial — You may not use the material for [commercial purposes](#).

NoDerivatives — If you [remix, transform, or build upon](#) the material, you may not distribute the modified material.

<http://creativecommons.org.nz/licences/licences-explained/>

Manipulating processing to generate meat quality attributes appropriate for diverse markets

N. J. SIMMONS, C. C. DALY AND K. V. GILBERT

Food Systems & Technology, AgResearch, Ruakura, Private Bag 3123, Hamilton, New Zealand

ABSTRACT

The optimal processing conditions for different meat quality attributes can often be conflicting. For example, conditions that maximise the rate of tenderisation may be responsible for increased drip and cooking loss, a reduction in colour stability and changes in textural characteristics. The conditions for optimal processing can therefore be defined as those conditions that establish the best compromise between conflicting meat quality requirements for different end-uses or markets. Methods of defining processing specifications tailored to defined endpoints are considered, specifically through the control of the rate of *rigor mortis* onset using combinations of electrical inputs and chilling regime.

Keywords: meat quality; meat processing; tenderness; texture

INTRODUCTION

New Zealand meat is presented to a number of diverse markets, and while the basic meat quality attributes required by the customers in these markets may be similar, the distance and time taken to reach them will be very different and these logistical issues might have the potential to adversely affect meat quality. However, studies during the last few years have demonstrated that, if processing is manipulated to allow for the subsequent differences in the transport and distribution chain, then the product attributes can be optimal for each of the markets.

The muscle environment during the pre-rigor is critical in determining the behaviour of myofibrillar proteins and then subsequent impact on key quality attributes such as tenderness, texture, succulence, drip loss, colour, and colour stability. The two main determinants in defining the pre-rigor conditions are the rate of pH fall and the rate of cooling. These two variables are obviously not independent as temperature will affect pH fall, but pH fall can also be manipulated independently by the level of electrical inputs applied to the carcass. Electrical inputs extend from electrical stunning, used to either kill the animal or render it unconscious prior to neck cutting, to the various forms of electrical immobilisation and stimulation that occur during and after the dressing procedures. Even electrical inputs used to stiffen the carcass during hide pulling need to be considered.

Initial research targeted fundamental information on the effects of temperature and pH fall on meat quality attributes. More recently, more practical issues have been considered, in particular the interactions of different electrical inputs and chilling rate. The results have been used to develop new and individual processes that optimise meat quality for different markets, and these will be extended to tailor processing scenarios to generate different functional properties for some of the niche markets available for New Zealand meat.

Defining processing limits - The effects of pre-rigor conditions

Tenderness

Eating quality is only one of a number of important considerations in meat processing: though important, it needs to be balanced with other requirements that include

production costs and food safety. The key to defining practical and effective processing options is to understand the limits at which eating quality becomes compromised by other commercial requirements.

The balance between conflicting requirements is evident in processing to control tenderness. The level of tenderness or toughness in meat is due to two features of the post-mortem muscle; first, the degree of sarcomere shortening and second, the level of proteolytic activity or tenderisation.

The classical studies of Locker and Hagyard (1963) first demonstrated that sarcomere shortening occurring at either low or high temperatures during the pre and at-rigor period respectively, will cause tough meat. Cold-shortening is a well recognised processing limit. Shortening between 20-40% produces severe toughening and this persists throughout ageing (Davey & Gilbert, 1973). Less well understood are the effects of high temperatures during the pre-rigor period. High temperatures (>30°C) can produce similar levels of shortening as low temperatures, but the effects on toughening are more complex. Meat that has been exposed to high pre-rigor temperatures does not show marked toughening when assessed instrumentally, but taste panels consistently describe such meat as tough (Hertzman *et al.*, 1993).

Pre-rigor temperature also plays a major role in determining the level of proteolytic activity during both the pre- and post-rigor period. Dransfield (1993) developed a theoretical model to describe the activities of calpains and calpastatin in response to temperature and used the model to predict meat tenderness. He proposed that high temperatures resulted in an early loss of enzyme activity, so that although proteolysis is initially rapid, the extent of proteolysis is limited.

In an effort to examine this model empirically and, more specifically, to consider the temperature effects independent of the rate of pH fall, calpain and calpastatin activity was compared at equivalent pH values in muscle that had been held at three different but constant pre-rigor temperatures. This work showed that, at the completion of rigor, μ -calpain was substantially depleted in muscle held at 35°C, but levels in muscle held at 15°C, and to a lesser extent the 25°C, were largely unchanged from the levels found at slaughter. Shear force measurements at rigor, showed that the 35°C samples had lower shear force scores than the 15 and 25°C

maintained muscles. In contrast, samples held at 15 and 25°C had lower shear force values than the 35°C samples after 4 days. These effects can be attributed to the balance between calpain induced proteolysis and loss of activity through autolysis. In the case of meat that enters rigor at high temperatures, calpains are activated and proteolysis will be rapid due to the high temperatures, but proteolysis will also be short-lived as inactivation through autolysis is also rapid. At lower temperatures, the balance is shifted towards a longer period of proteolytic activity due to a slower rate of autolysis.

Calpain activity tended to increase once the pH had fallen to 6.2. Subsequent studies using similar protocols but using electrically stimulated muscle generated the same increase in activity at this pH. It therefore appears that calpain-induced proteolysis begins when the pH has fallen to 6.2 and, depending upon the temperature at this time, can result in a significant degree of ageing prior to the full development of when the pH of 5.6 to 5.5 is attained.

Changes in sarcomere length were also measured during this work. As reported by Devine *et al.*, 1999, the muscles shortened more when maintained at 35°C pre-rigor compared with either 15 or 25°C. While this increased shortening may have induced some toughening, the meat was not particularly tough (shear force > 11 kgf) and it was concluded that pre-rigor calpain activity rather than sarcomere length contributes to eating quality in high pre-rigor temperature conditions.

Texture

Meat held at higher temperatures during the pre-rigor period is described as tough by sensory panellists but the shear force values were not particularly high (Olsson *et al.*, 1994). The reasons for this discrepancy still remain unclear, but it is likely that textural attributes, independent of tenderness, are also affected by the pre-rigor temperature regime. Obviously, if meat is unacceptably tough, then texture is relatively unimportant, but once meat is acceptably tender other textural attributes relating to juiciness, fragmentation and other undefined characteristics commonly referred to as mouth-feel, become important. At present, there are no objective methods for measuring these alternative textural attributes such texture or the 'mouth-feel' of meat, but sensory panellists can be trained to measure cohesiveness, fibrousness, softness, succulence and juiciness.

Our recent trials using trained texture panels found that meat held at high temperatures pre-rigor, while generally perceived as tender, may suffer a deterioration in other textural attributes, or may develop a different set of dominant attributes. Meat that undergoes rigor between 30-35°C was softer and less fibrous compared to samples that had undergone rigor at 15-20°C. Scores for both fibrousness and cohesiveness were significantly different, although the shear force for these different samples was not statistically different. This work was a useful demonstration of how the normally reasonable correlation between shear force and taste panel assessments of tenderness is lost in meat that has been exposed to high pre-rigor temperatures. Subsequent trials using untrained consumer panels showed that consumers expect a certain textural experience when

eating meat, and exposing carcasses to high temperature rigor treatments produces meat that lacks fibrous and cohesive qualities. These characteristics were deemed less acceptable.

These results may explain in part why past research has reported that high temperature rigor has generated samples that are equivalent in shear force values to lower rigor samples but are perceived as tougher when measured by panellists. Untrained panellists may simply mark such samples as tougher because they find them less acceptable.

Defining processing scenarios

The development of meat quality under a range of pre-rigor temperature conditions has provided baseline understanding on the impact of the pre-rigor environment on the resultant meat quality. The next step is to utilise some of the features of processing such as stunning, immobilisation, stimulation and chilling to control the pre-rigor environment of the muscle and generate optimised quality for different markets. For example, a processor preparing meat destined for the local market requires tender meat within a few days. In contrast, a chilled meat exporter has the advantage of several weeks of chilled storage in which ageing can take place. These different markets translate into different processing options.

A wide variety of different processing procedures are used in both lamb and beef processing in New Zealand. Many processes that were developed in the 70s and 80s were directed at frozen lamb, but this market has shrunk and new options based on chilled meat have developed. Some procedural changes have also arisen from the need to improve welfare, which resulted in the introduction of electrical stunning. More recently, as throughput's have increased, the amount of post-slaughter convulsive activity had to be reduced to allow faster line speeds and also to avoid worker injury. Low voltage currents are therefore applied after sticking to immobilise or quieten the carcass. In lambs, an additional burst of a high voltage current can also be for the same reasons, a procedure now known as spinal discharge. These new procedures were grafted onto the existing processes without consideration of the impacts on meat quality. Therefore, we have reassessed the effects of different combinations of stunning, immobilisation and stimulation procedures on the rate of pH fall, pre-rigor temperature profile and tenderness (Table 1).

TABLE 1. Effect of stunning and stimulation treatment combinations on the pre-rigor temperature profile and shear force in beef carcasses exposed to a chill regime of 10°C for 16 hours then 4°C for 8 hours

Treatment	Temp @ pH 6.2	Temp @ pH 5.6	Kgf 1 day	Kgf 7 days
CB	13	9	14.0	5.5
CB + LVS	32	14	9.5	8.0
CB + HVS	34	15	6.7	6.2
Halal	25	12	13.1	5.1
H ₂ B	31	12	9.4	5.8
H ₂ B + LVS	35	15	9.1	5.9

Key CB = Captive bolt stun, no stimulation. CB + LVS = Captive bolt stun, low voltage stimulation. CB + HVS = Captive bolt stun, high voltage stimulation. Halal = Head only stun, low voltage immobilisation/stimulation. H₂B = Head to back stun, no stimulation. H₂B + LVS = Head to back stun, low voltage stimulation

Clearly, electrical inputs tend to accelerate the rate of pH decline. Thus, electrical stunning results in a lower pH compared to mechanical stunning methods such as captive bolt. Furthermore, electrical stunning when applied in a head-to-back electrode configuration results in a lower pH than a stun that is applied to just the head, due to the greater amount of muscle stimulation in the loin area. The magnitude of the pH response to electrical inputs after bleeding depends on the type of current. For example, low voltage stimulation (< 200 volts) will generally produce 0.3 to 0.5 units of pH drop during the stimulation but will have very little affect on the subsequent rate of pH fall. In contrast, high voltage stimulation generates on average 0.5 pH fall and also accelerates the rate of change after stimulation. However, while these are useful 'rule of thumbs', the response to stimulation is also affected by preceding electrical inputs. While the nature of these interactions is not fully defined, it is evident that as the pH falls, the muscle becomes less responsive to electrical stimulation and responsiveness ultimately disappears.

Despite some of the apparent anomalies with electrical interactions, it is clear that electrical inputs generally accelerate the development of tenderness in two ways: since proteolysis begins as the pH falls to approximately 6.2, an earlier onset of this pH increases the total time available for proteolysis. Additionally, since the early rate of tenderisation is temperature dependent, an earlier onset of rigor is associated with a higher carcass temperature and therefore the initial rate of tenderisation is accelerated.

Thus, armed with these pH profiles and the curves relating to the temperature dependence of proteolysis, one can bring together process formations that will result in a pre-rigor environment that will generate the desired meat quality outcomes.

To illustrate this, two contrasting processing regimes were applied to beef carcasses in an effort to generate meat quality attributes suitable for a chilled overseas product and a chilled product destined for the local market. The aim of these processes was to generate two very different rates of rigor development, and the meat quality of some of the major muscles was measured after different periods of chilled storage. The slow rate of rigor process consisted of a captive bolt stun with no subsequent electrical inputs followed by chilling at 4°C for 24 hours. In contrast, the fast rigor process consisted of head-only electrical stun (Halal) with 15 seconds of low voltage immobilisation (180mA) and high voltage stimulation (1130 Volts for 90 seconds) applied to the dressed carcass at 30 minutes post-mortem and chilled at 10°C for 15 hours then 4°C until 24 hours. These two processes were selected to ensure that the temperature of the m. *longissimus dorsi* (LD) from 6.2 to rigor (5.6) was between 10 and 6 °C for the slow rigor process (chill export product) and 30 and 24°C for the fast rigor process (chill local product).

The fast rigor process resulted in significantly lower shear force values in the LD muscles than the slow rigor process. From the fast rigor process, the LD was considered as a highly acceptable product (as judged by consumer panels) after 7 days of ageing while the slow rigor samples took 21 days to reach equivalent scores. However, after 60 days of storage the slow rigor samples had aged further

and generated lower shear force scores than the fast rigor samples. For two other muscles, the BF and SM, the shear force was unaffected by the rate of rigor onset, but the fast rigor treatment resulted in significantly higher fluid losses and a reduction in colour stability during simulated retail display compared to the slow rigor treatment.

This work illustrates some of the complexities associated with process tailoring: The effects of pH/temperature profiles on both proteolytic activity and protein denaturation are reasonably well understood for the LD. However, while the temperature profile of this superficial muscle is easy to control and manipulate, it is much harder to control the temperature profiles of the deeper muscles when using traditional cold-boning techniques. Techniques such as hot-boning combined with some of the newer technologies such as immersion chilling create the opportunity to control and define the pre-rigor temperature/pH decline on an individual muscle basis. These opportunities allow the pre-rigor environment to be tailored to generate meat quality outcomes for different markets. Additionally, individual muscles, whose size and fiber type differ, can be processed in a manner that will improve both the quality consistency while also offering possibilities to upgrade the qualities of these muscles to a level that is comparable to some of the higher value muscles.

REFERENCES

- Davey, C.L., Gilbert, K.V. 1973. The effect of carcass posture on cold, heat and thaw shortening in lamb. *Journal of Food Technology* **8**: 445-451.
- Devine, C.E., Wahlgren, N.M., Tornberg, E. 1999. Effect of rigor temperature on muscle shortening and tenderisation of restrained and unrestrained beef m. longissimus thoracicus et lumborum. *Meat Science* **51**: 61-72.
- Dransfield, E. 1993. Modelling Post-Mortem tenderisation 4. Role of calpains and calpastatin in conditioning. *Meat Science* **34**: 2, 217-234.
- Hertzman, C., Olsson, U., Tornberg, E. 1993. The Influence of high temperature, type of muscle and electrical stimulation on the course of rigor, ageing and tenderness of beef muscles. *Meat Science* **35**: 119-141.
- Locker, R.H., Hagyard, C.J. 1963. A cold shortening effect in beef muscles. *Journal Science Food and Agriculture* **14**: 787-793.
- Olsson, U., Hertzman, C., Tornberg, E. 1994. The Influence of low temperature, Type of muscle and electrical stimulation on the course of rigor mortis, ageing and tenderness of beef muscles. *Meat Science* **37**: 115-131.