

Evaluation of the pH fall in English lamb abattoirs against the Meat Standards Australia pH/temperature window

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Introduction

It has long been understood that there are two types of muscle shortening resulting in toughness and that these can be monitored by observations of pH/temperature changes with time. Under standard processing conditions pH is assumed to fall in a fairly consistent manner. It is therefore generally adequate to monitor temperature change with time as a means of ensuring that rigor mortis occurs at an appropriate temperature to avoid excessive shortening. This has been expressed as the “10 in 10 rule” (MLC, 1994). Developments in abattoir practice, however, mean that a standard pH decline can no longer be assumed. In particular the introduction of electrical stimulation to enhance tenderness and other electrical inputs on the slaughterline increase the rate at which rigor occurs. This means that the simple rule is no longer appropriate and there is an increased risk of hot shortening.

The evaluation of the pH/temperature relationship in beef plants in England completed in 2008 demonstrated that both hot and cold shortening is occurring in commercial beef slaughtering facilities. It was considered likely that the control of the pH/temperature relationship in sheep plants has also diverged from best practice over time.

New Zealand work reviewed for the 2008 International Congress of Meat Science and Technology (Simmons *et al.*, 2008) has shown that different electrical stimulation parameters can elicit different responses, but the authors believe the effect of electrical stimulation is the direct effect of changing the rate of pH fall on proteolysis.

The most clear guidelines currently available on the target pH temperature relationship post slaughter for sheep, come from work jointly funded by the Australian Sheep Industry Cooperative research Centre and Meat and Livestock Australia (CRC for Sheep Industry Innovation, 2007). Their guidelines are that the temperature should be between 18 and 35°C when the pH drops below 6. This can probably only be achieved with the application of stimulation. However, the target is extended where pelvic suspension or ageing of 10 days or more is applied. In this case the temperature should be 8 to 35°C when the pH drops below 6.

In this project the pH and temperature relationship post slaughter was evaluated against these targets in five English lamb plants.

Approach

Temperature and pH were monitored following slaughter in five lamb plants in England. The results were compared with the optimum recommended in the Australian guidelines, as well as the original MLC Blueprint. These results have provided valuable information to make recommendations to the individual plants concerned, and more widely, for changes in practice that should be made in order to reduce any toughening effects of shortening. Inevitably, the trial took place on a relatively narrow batch of animals so the results should be viewed as an indication of the risks of shortening rather than a definitive determination of the incidence.

Objective

To evaluate the pH / temperature relationship in lamb slaughter plants in England in comparison with published guidelines.

Materials and Methods

Plant visits

Five lamb slaughterers in England participated in the study to cover a range of practices (in particular in relation to chilling rates and use of electrical stimulation).

Where possible, each plant was visited on two slaughter days to take pH and temperature measurements. Lambs were measured on the day of slaughter for two slaughter days and the following day (to obtain ultimate pH).

Selection of lambs

Lambs within the first hour's kill were selected for monitoring. Twenty carcasses were measured on each of the two day's kill as far as possible. In some cases carcasses were lost (through commercial operations) before a full set of measurements was taken and therefore the numbers were reduced.

pH / temperature measurement

pH and temperature were measured in the *Longissimus lumborum* of every carcass:

- where electrical stimulation was not applied, at 45 minutes post slaughter and regularly thereafter until pH 6 was achieved (or the plant locked down for the night).

- where electrical stimulation was applied, immediately after stimulation, with additional measurements until pH 6 was achieved (or a temperature of 8°C).
- At 24 hours post slaughter in all plants.

In addition, data loggers were used to monitor temperatures in a sample carcass on each slaughter day.

Data analysis

For each carcass the temperature at which the pH reached 6.0 was determined by interpolation graphically. This was then used to compare the performance against the Meat Standards Australia recommendation. In addition the effects of carcass traits were examined by Analysis of Variance or regression as appropriate. Ultimate pH was also examined.

Summary of Results and Recommendations

Detailed results will be reported to individual plants participating in the study. The main findings are given in summary here.

No electrical stimulation

1. Causes for variation in chilling rate in the same plant are not clear, although partly the result of differences in environmental temperatures. This variation leads to variation in the risk of cold shortening.
2. There was a risk of cold shortening, indicated by a pH of 6 or more at a temperature of 18°C, in a number of carcasses, and this varied by day, but in no plant was there a severe risk of cold shortening (pH of 6 or more at a temperature of 8°C).
3. Following the MLC recommendation of ensuring that no muscle should fall below 10°C within 10 hours of slaughter would be a good basic measure to reduce the risk of cold shortening. As cold shortening conditions only occur in a proportion of carcasses, it is necessary to monitor temperature in a wide sample of carcasses.

High voltage electrical stimulation

1. The electrical stimulation was highly effective in reducing pH and no carcasses had a pH of more than 6 by the time a temperature of 18°C was achieved, indicating no risk of cold shortening.
2. The pH fall in a high proportion of carcasses was too rapid, resulting in a pH of less than 6 while the temperature was at 35°C or above. This indicates that hot shortening is likely to be occurring, particularly in the more difficult to cool muscles of the leg.
3. MLC guidelines for chilling rate do not take account of the risk of hot shortening and the introduction of an MSA-style pH-temperature window would provide industry with a useful guide.
4. Chilling rate could be more rapid (in the light of the fact that ES is in use) to reduce drip loss and the risk of hot shortening.

5. Measurement of pH immediately post-stimulation is insufficient to detect hot shortening and more detailed monitoring is required to establish the best time for routine measurement in the specific circumstances.

Overall

1. Ultimate pH was normal where it was measured.
2. Carcase chilling is affected by the carcase weight such that the risk of cold shortening is lower in heavier carcasses.
3. Chilling conditions should be targetted to meet carcase characteristics where possible.
4. Effective monitoring of pH in a sample of carcasses is a useful tool to improving consistency in meat quality, through reducing the risk of shortening.

ANNEX – muscle shortening

Muscle contracts (shortens) naturally as it goes into rigor mortis if it is not restrained from doing so. Most muscles are under tension when the skeleton of the carcass is in its normal posture. If muscle is restrained it will develop tension as it goes into rigor but will not be able to shorten in its overall length. The extent to which muscles are able to shorten depends on the remaining energy (ATP) available at the time of shortening, the load on the muscle and the temperature of the muscle when these events occur. A shortened muscle has shorter sarcomere lengths, ie shorter repeating units within the contractile myofibrils and a greater overlap between the contractile filaments.

Shorter sarcomere lengths are generally associated with tougher meat. In shortened muscle shear force values can increase by over 300%, but the response is not linear with the degree of shortening. Tenderness has been noted to be at its lowest with 25-40% shortening and severely shortened muscle (which had shortened 60%) was as tender as unshortened muscle (Marsh and Leet, 1966).

The temperature effect on the ability to shorten during rigor is particularly interesting, with the extent of beef muscle shortening varying with temperature at which rigor occurred according to the sequence $1 > 37 > 5 > 20^{\circ}\text{C}$ (Busch *et al.*, 1967). It is now generally accepted that there are two types of shortening and that for minimum shortening muscle should be at about 15°C as it enters rigor mortis. This can never be achieved in practice for all muscle fibres because of the different rates of cooling in different locations of the carcass and the different rates of rigor development in different fibres. It is however a useful guideline and has been expressed in the MLC Beef Blueprint as the “10 in 10 rule” ie no muscle should fall below 10°C in the first 10 hours after slaughter (MLC, 1990).

Cold shortening occurs if the muscle is exposed to low temperature, say less than 11°C (Locker and Hagyard, 1963) prior to the development of rigor. Under these conditions the muscle spontaneously contracts and, since it does so at relatively high levels of ATP and pH, the degree of contraction can be considerable. Adherence to the 10 in 10 rule is an effective means of avoiding cold shortening under normal conditions.

The shortening that occurs with rigor above 20°C occurs as the energy supply is being exhausted and it is, therefore, generally quite weak. This form of rigor shortening is termed hot shortening. Its importance has been debated but with increasing use of electrical stimulation and other electrical inputs on the slaughterline the opportunity for rapid pH fall and rigor development while the carcass is still relatively hot is increased, and with it the risk of hot shortening. In these circumstances the 10 in 10 rule is no longer useful and more rapid chilling may become appropriate.

References

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