MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

Meat technology update

2/11 – March 2011

Heat toughening—Part 1:
Effects of heat toughening on quality of beef, and the incidence in Australia

- **Heat toughening occurs when the carcase pH falls rapidly, and reaches pH 6 while the carcase temperature is still greater than 35°C.**
- **Heat toughening has detrimental effects on colour, texture, amount of weep produced, tenderness and eating quality.**
- **Heat toughening is likely to occur in modern processing plants.**

Figure 1: MSA personnel measuring the pH-temperature in the loin muscle of a beef carcase

When the consumer buys meat, visual cues for quality include a bright red colour, low fatness levels and the absence of weep in the tray. On consumption, the consumer expects the meat to be tender, juicy and flavourful, with no abnormal flavours or odours. Understanding the factors that contribute to variations in these quality traits assists in determining strategies to optimise the quality traits. The concept of a pH/temperature window was one of the initial specifications for the Meat Standards Australia (MSA) grading scheme in Australia, and was designed to minimise the detrimental effects of extremes in processing i.e. heat toughening and cold shortening. The MSA scheme is aimed at predicting eating quality of individual cuts using a total quality management approach. The pH-temperature window was developed from the meat science literature available from around the world, which generally shows that minimal shortening in muscles occurs when carcases enter rigor at approximately 15°C to 20°C, resulting in optimum tenderness.

Electrical stimulation of beef carcases was introduced in order to accelerate the rate of post-mortem pH fall to allow more rapid rigor onset and prevent cold-shortening. Most of the standards set down for electrical stimulation in the 1970s were based on the assumption that electrical stimulation was the only electrical input on the slaughter floor. While this assumption was generally true at the time, this no longer applies. Beef processing plants now have a number of possible electrical inputs on the slaughter floor, including the immobiliser, bleed stimulator, electrical stimulator and the hide-puller stiffening probe. There is also evidence that the pH of especially heavy grain-fed cattle, falls more rapidly than that of the lighter cattle processed 30 years ago. Thus the challenge in beef processing now appears to be slowing down the rate of pH fall post-slaughter, rather than speeding it up.

Heat toughening is caused by a fast rate of pH fall while the carcase is still hot. The region to avoid in the pH-temperature window is the red section in Figure 2. If the pH-temperature decline in a carcase goes through this red region, it is defined as a 'heat-toughened' carcase. The loin temperature at pH 6 is calculated from the pH-temperature-decline data measured in the loin muscle pre-rigor.

Definition of heat toughening: A heat-toughened carcase is defined by having a temperature at pH 6 >35°C, during the pre-rigor period.

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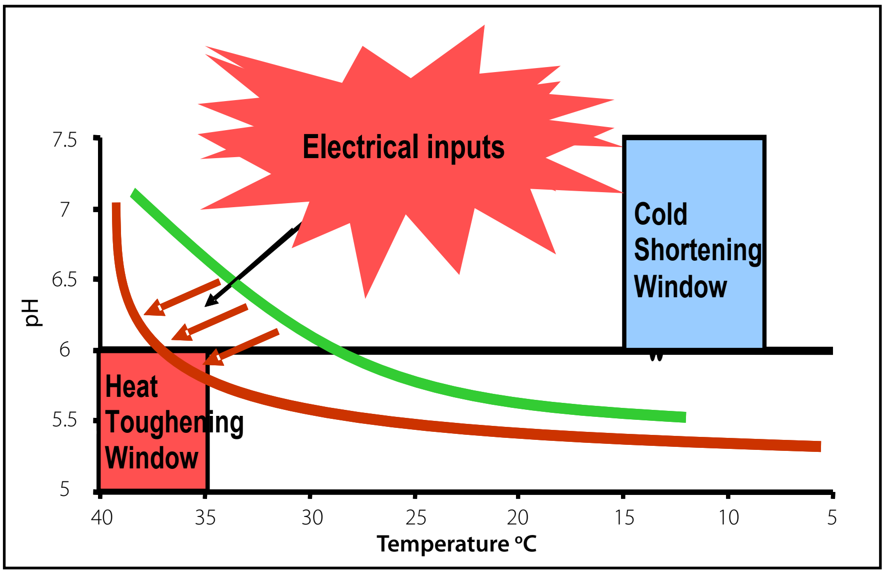

Figure 2: pH temperature window showing the decline in pH and temperature post-mortem in the loin muscle. The regions to avoid, to ensure quality meat, are the cold-shortening region and the heat-toughening region.

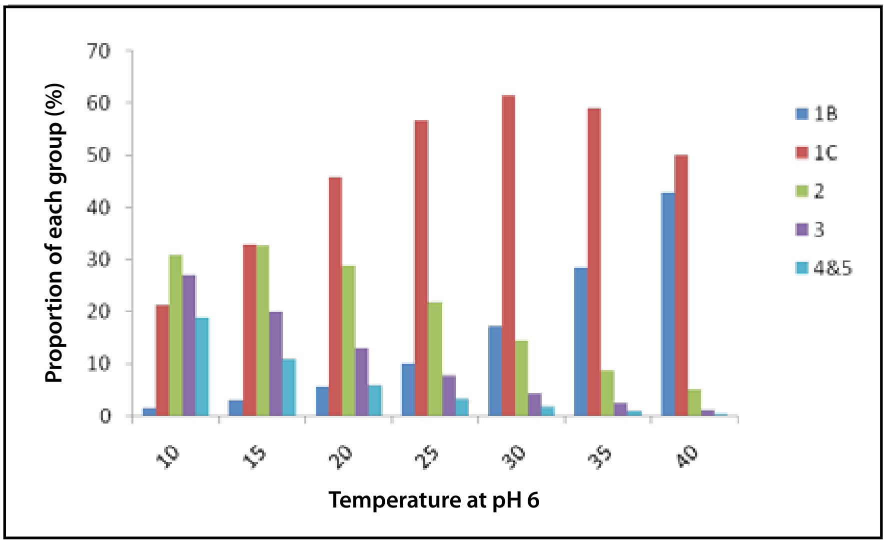

Figure 3: Effect of temperature at pH 6 on the AUS-MEAT colour score . Higher scores are darker; scores 4 & 5 are unacceptably dark.

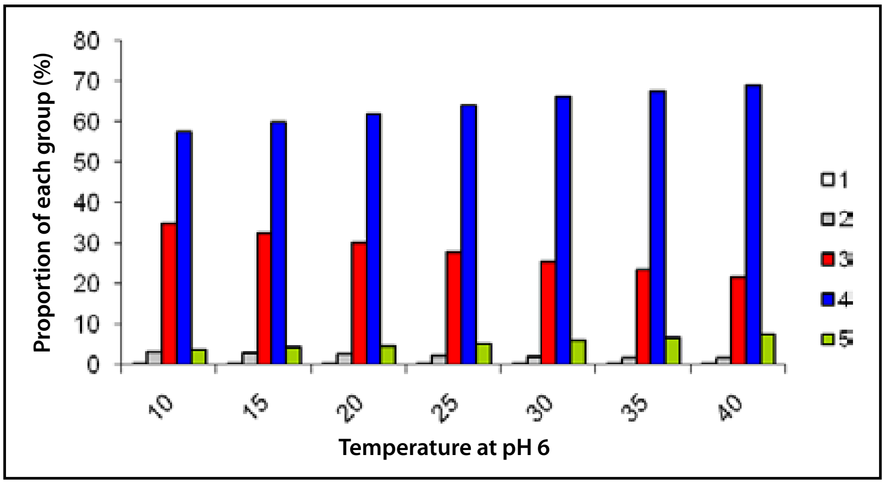

Figure 4: Effect of temperature at pH 6 on the texture score. 1 = firm, fine; 5 = coarse, soft

What are the effects of heat toughening on quality?

Colour: A paler colour occurs in muscles which are heat toughened. In carcases with a loin temperature at pH 6 of 35–40ºC, there is an increase in striploins with AUS-MEAT colour score 1B and 1C at grading, and a decrease in striploins with AUS-MEAT colour score 2, 3 and higher (Figure 3). Some markets for beef have a preference for paler meat colour, particularly AUS-MEAT colour scores 1B and 1C. The quality problems associated with the paler colours in heat-toughened beef are the higher weep, or purge, as well as other eating-quality problems described below. Initial research on modifying the frequency and pulse width of the current applied during electrical stimulation indicates there is some potential to increase the number of beef carcases meeting grading specifications for AUS-MEAT colour scores in beef. This can potentially be achieved through applying modulated frequency electrical stimulation, without influencing the occurrence of heat toughening. This warrants further investigation.

Texture: Heat-toughened meat shows a greater prevalence of texture score 'coarse and soft' (high scores), and a lesser prevalence of texture score 'firm and fine' (low scores) (Figure 4).

Wetness: At grading, the loin of a heat-toughened carcase often shows beads of moisture exuding from the meat surface (Figure 5). When MSA graders gave the surface of 1,512 loins at grading a score of 0 for no weep, or 1 for presence of weep, the average weep score increased as the temperature at pH 6 increased (Figure 6).

Tenderness and eating quality: MSA consumer data from 3,864 striploins was analysed for the effect of temperature at pH 6 on eating quality. After accounting for the other factors known to influence eating quality and tenderness (ossification, carcase weight, marbling, cook method, ageing, carcase-hanging method), temperature at pH 6 was found to significantly influence eating quality and tenderness. The striploin from heat-toughened carcases is initially more tender, then shows a failure to age, when compared to striploins going through an ideal temperature at pH 6 of 15ºC (Figure 7). MSA eating-quality data from 942 rumps aged for 5 to 28 days showed that rumps from carcases defined as heat-toughened in the striploin, would be about 5 consumer units lower in acceptability than rumps going through the ideal pH-temperature window (Figure 8).

Figure 5: Striploin at grading showing the weep on the surface of the loin of a heat-toughened beef carcase

Survey of the incidence of heat toughening in beef

From an MLA-funded survey of 1,512 beef carcases in 7 abattoirs during 2007/2008, the overall incidence of heat toughening was 74.6%. Thus the occurrence of heat toughening in beef carcases is prevalent in Australia. The incidence varied from 56 to 94% between the abattoirs. The survey highlighted some factors contributing to the incidence of heat toughening in beef carcases.

Feed type: Of the carcases included in the survey, 72% were finished on grain, 24% on grass and 4% were on milk, with the respective frequencies of heat toughening being 76.5%, 58.4% and 20.1%. Thus it is evident that heat toughening is particularly prevalent in grain-fed cattle, but also has a high frequency in cattle finished off pasture. It is particularly surprising that milk-fed vealers exhibited 20% heat toughening, as this category is usually susceptible to cold-shortening. It was evident that the two plants that were slaughtering milk-fed veal had not optimised their immobiliser settings. This has since been rectified (see Part 2 for recommendations for immobilisers).

Category of cattle: Table 1 shows how the incidence of heat toughening varied amongst the categories of cattle. Grass-fed cattle overall had a lower incidence of heat toughening, and the incidence varied from 46% for cows, to 68% for ox. For grain-fed cattle, the lowest incidence was for cattle fed grain for 60–70 days (46%); and the incidence rose to 81% for cattle fed grain for 100–200 days; and reached 94% for cattle fed grain for 340–350 days.

Hot carcase weight: Hot carcase weight was strongly correlated to days on grain. Thus as the hot carcase weight increased, so did the incidence of heat toughening.

Table 1: Incidence of heat toughening amongst different categories finished on either grain or grass.

		Number	% heat toughening
Grain finished	Days on grain		
	60-75	211	46.0
	100-200	646	80.8
	214-300	128	92.2
	340-350	97	93.8
Grass finished	Category of cattle		
	Yearling (non-MSA)	70	56.2
	MSA	93	64.5
	Cow	79	45.6
	Ox	78	67.9

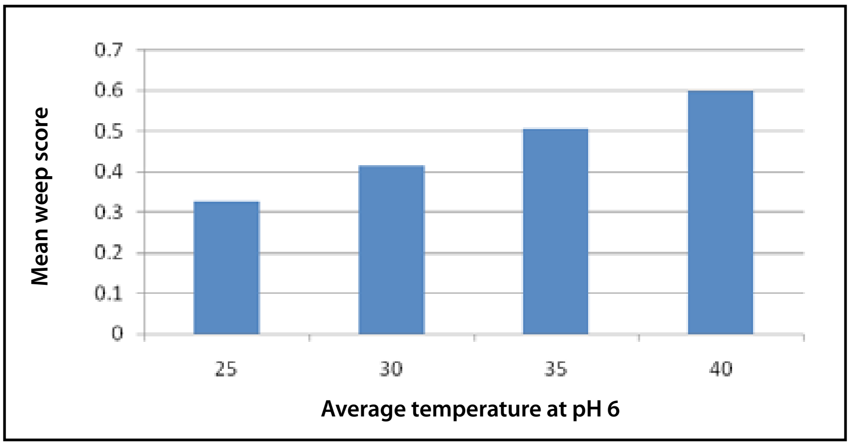

Figure 6: Effect of temperature at pH 6 on the weep score on the surface of the striploin at grading . 0 = no weep; 1 = obvious weep. The chart shows the average score for all the loins in each temperature group.

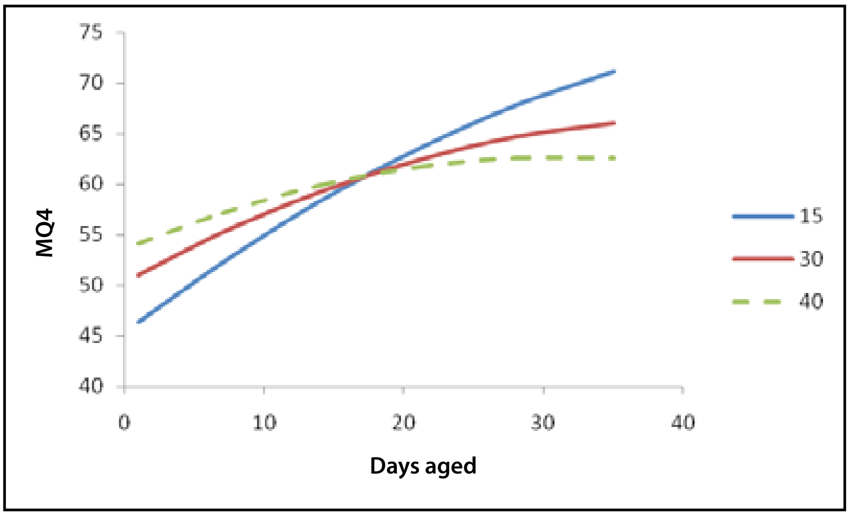

Figure 7: Effect of temperature at pH 6 (TatpH6) and days aged on the predicted MQ4 score for grilled striploin. A low MQ4 score is less acceptable to the consumer and a high MQ4 score is more acceptable.

Electrical inputs on the slaughter floor: The main influence of electrical inputs on the slaughter floor is through the rigidity probe at the hide puller. Recommendations for optimising the rigidity probe and other electrical inputs are given in Part 2. In almost all plants undertaking the heat-toughening study, electrical inputs were in many cases not optimal, and adjustment and optimisation of settings significantly reduced the incidence of heat toughening. Optimising electrical input should be the first response if high incidences of heat toughening are observed.

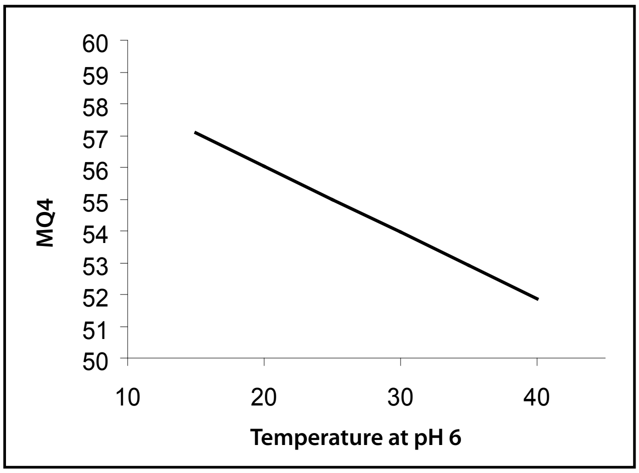

Figure 8: Effect of temperature at pH 6 on predicted MQ4 score for rump. A low MQ4 score is less acceptable to the consumer, and a high MQ4 score is more acceptable.

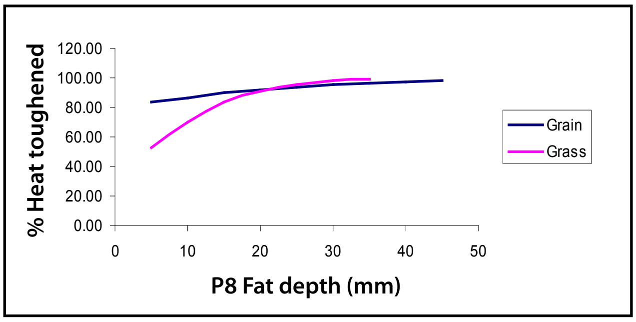

Figure 9: The effect of feed type and P8 fat depth on the predicted % heat toughening

Fat depth: The effects of fat depth were independent of carcase weight, but dependent on feed type. There was little influence of P8 fat depth in grain-fed cattle, on the predicted % heat toughening, but a large influence with grass-fed cattle. Grass-fed lean cattle (P8 = 5 mm) had a relatively low predicted incidence of heat toughening (54%); but in grass-fed fat cattle (P8 = 30 mm), the predicted incidence of heat toughening was high (87%) (Figure 9).

Sex: Females had a lower predicted temperature at pH 6 and a lower predicted % heat toughening than male cattle (71 vs 83% respectively), with the difference being bigger for fat cattle.

A final note on ageing

The effects of heat toughening on quality and eating quality when ageing beyond the normal domestic ageing period (beyond 35 days) is largely unknown and warrants further investigation.

What is the commercial benefit to a beef processor in eliminating heat toughening?

According to one domestic beef processor who originally had excessive stimulation of his beef carcases on the slaughter floor, the big benefit is in improved product performance. The processor stated that although he originally had more beef carcases with AUS-MEAT colour score 1B and 1C, he also had complaints from customers about sloppy meat and water in the bag. He also had comments about two-toning, inconsistent colour and the meat being 'dry' to eat. Now that the processor has optimised the temperature at pH 6 in beef carcases, his customers are much happier with the product performance and consistency.

Summary

Heat toughening can have significant detrimental effects on meat quality, and a number of factors can contribute to heat toughening. There are also a number of ways in which the incidence of heat toughening can be reduced. These are discussed in Part 2.

The information contained herein is an outline only and should not be relied upon in place of professional advice on any specific matter.

Contact us for additional information

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