Meat technology update

99/4 – July 1999
Reprinted November 2006

Post-slaughter aspects of beef eating quality

The eating quality of meat is a function of the animal production and carcase processing that has been applied. While live animal factors (animal age, nutrition, breed, pre-slaughter stress) often have a marked effect on beef eating quality, in many cases the treatment of the carcase on the slaughter floor and in the chiller can have a far greater effect. This update, which follows on from *Meat Technology Update* Newsletter 99/1 (A Critical Control Point approach to beef eating quality), discusses post-slaughter aspects of beef eating quality.

Post-slaughter changes in muscle

Immediately post-mortem, there are two related processes that affect eating quality:

- A fall in muscle pH and temperature
- Shortening of the muscle.

In turn, these two processes affect a third process which also significantly influences eating quality:

- Breakdown of muscle proteins by enzymes (proteolysis or ageing).

The combination of a very rapid fall in pH and slow cooling of the carcase can lead to heat or rigor shortening, whereas a slow fall in pH and rapid cooling can lead to cold shortening (see *Meat Technology Update* Newsletter 99/1). Heat shortening is undesirable in terms of eating quality as it causes dryness and slight to moderate toughness; cold shortening is undesirable as it can cause moderate to severe toughness. A less obvious but important penalty of both cold and heat shortening is a reduction in the ability of the meat to age. Thus, the aim is to achieve an optimal rate of pH fall and/or the mechanical prevention of shortening. Strategies for the production of tender meat therefore include:

- Optimisation of rate of pH and/or temperature decline
- Minimisation of degree of shortening
- Maximisation of the ageing potential of the meat.

The optimal rate of pH fall

Electrical inputs

The application of an electric current to beef carcases on the slaughter floor was introduced to accelerate pH decline relative to carcase cooling and so avoid cold shortening. Traditionally, the current has been applied with an electrical stimulation (ES) unit, which may be either extra-low voltage (ELV, usually applied after stunning/sticking) or high voltage (HV, usually applied to the carcase after hide removal or to the dressed beef side).

Often, ES was the only electrical input applied during slaughter. However, in many works, carcases receive electrical

MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

FOOD SCIENCE AUSTRALIA
A joint venture of CSIRO & the Victorian Government

AMPC

mla MEAT & LIVESTOCK AUSTRALIA

inputs over and above those supplied by stimulation units. The widespread use of downward hide pullers means that carcases receive an electrical current via the rigidity probes during hide pulling. Furthermore, to assist with occupational health and safety responsibilities, immobilisers are often used after knocking. The term 'electrical inputs' refers to all currents applied to the carcase on the slaughter floor and could include:

- electrical stunning;
- immobilisation;
- hide-puller rigidity probes;
- conventional electrical stimulation.

These electrical inputs are additive in terms of their effect on the rate of pH decline and lead to the early onset of rigor mortis. In some abattoirs where ELV and downward hide pullers are used, carcases have attained close to ultimate pH (5.5-6.0) 60 minutes after stunning. 'Overstimulation' in this instance is undesirable as it increases the risk of heat shortening and reduces the ageing potential of the product (see below). Another recent observation is that the rates of pH decline from conventional electrical stimulation are generally faster than those reported during the development of stimulation protocols in the seventies. It is not clear why this has occurred.

Electrical inputs and eating quality

The impact of the rate of pH decline on meat tenderness was investigated by the Cooperative Research Centre for the Cattle and Beef Industry (Meat Quality). Rate in this instance is based on the pH of the muscle at 1.5 hours after stunning. The results are illustrated in the Figure below. The 3 lines are for product that had been aged for 1, 7 or 14 days.

It can be seen that, for product aged for 1 day, the faster the pH decline (i.e. lower value at 1.5 hours) the more tender the meat. Given that Australian beef typically undergoes some period of ageing, a more moderate rate of pH decline (i.e. a pH of 5.9-6.0 at 1.5 hours) is desirable. Consequently, it is imperative that the various electrical inputs are monitored and the ES is adjusted accordingly to achieve this rate. Note that with little or no stimulation (pH values > 6.2

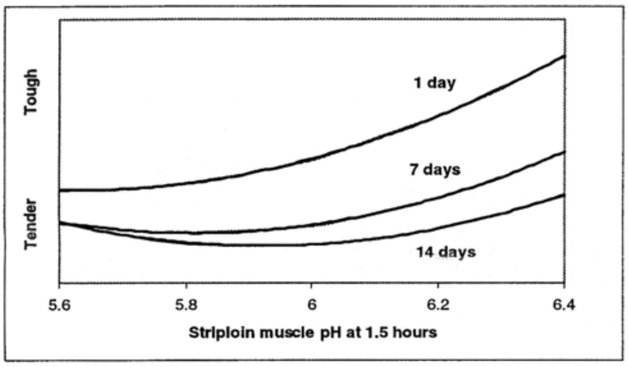

FIGURE 1 The effect of muscle pH and ageing on meat tenderness

at 1.5 hours) or ageing, the product was tough. A rapid fall in pH (low pH values at 1.5 hours), as would occur with stimulation, without ageing improves the product but its tenderness is still slightly inferior to that of aged product. This is because the action of the enzymes that improve tenderness by breaking down the muscle fibres has been compromised by the rapid pH fall at high temperatures.

Another possible effect of excessive electrical inputs is the development of a condition similar to Pale Soft Exudative (PSE) pork. If the pH drops very rapidly while the muscle temperature is high there may be considerable fluid loss from the muscle. This in turn may, but not always, lead to lack of juiciness and therefore inferior eating quality. The combination of ES, heavy carcases and poor chilling may lead to a PSE meat-like condition, particularly in the deep butt cuts. The same combination may also contribute to the development of two-toned meat, a condition in which there are undesirable gradations in meat colour within a cut, with the deep meat tissue being paler than the normal red meat closer to the surface.

Electrical inputs and meat colour

In the first 48 hours after slaughter, a muscle from a stimulated side is likely to be lighter in colour than a muscle from a non-stimulated side of the same carcase. If grading is conducted before the non-stimulated sides reach their ultimate pH, then stimulated sides will have a lighter colour score at grading. This is one of the reasons for the continued use of ES in the USA. Once the muscles from both the stimulated and control sides have reached their ultimate pH it is unlikely that there will be any major colour differences as a result of stimulation.

Extra-low-voltage (ELV) or high-voltage (HV) stimulation?

ELV systems tend to be low cost, labour intensive (although automated versions have been developed), whereas HV systems tend to be high capital cost (largely due to the safety requirements related to the use of the high voltages), automated systems. In practice, ELV stimulation has been applied early in the slaughter process (immediately after exsanguination); HV stimulation has been applied later in the slaughter process (after hide removal or to the beef side).

Comparisons between low and high voltage systems have generally shown that high voltage systems result in more tender meat than low voltage systems. Recent work has confirmed that it is the time of application that is important, rather than the type of stimulation system. Thus, the possibility exists of using ELV stimulation at the end of the slaughter floor, just before chiller entry. ELV application at this point may provide adequate stimulation, particularly if other electrical inputs are applied on the slaughter floor. Application here may be more desirable in terms of optimising the rate of pH decline and avoiding the problem of heat shortening. Further investigations are required, however, before this procedure can be recommended.

Another benefit of ELV ES is that it improves blood recovery. ELV ES applied after bleeding may have either desirable or undesirable effects at the legging station. A minimal amount of electrical input may reduce the involuntary hind leg movement that can occur when the skin is incised and thus contribute to worker safety. On the other hand, a disadvantageous effect may sometimes be encountered in that 'overstimulation' can lead to the rapid onset of rigor mortis, which results in a stiffening or fixation of the hind leg. ELV ES may also lead to an increased incidence of broken backs when downward hide pullers are used.

Duration of stimulation

Factors that need to be considered in determining the requirements for ES include:

- other electrical inputs which have been applied on the slaughter floor;
- the chilling rate - with slow chilling, ES is less necessary as there is a reduced chance of cold shortening BUT remember that chilling rates must comply with requirements for food safety and hygiene;
- any subsequent ageing - the longer the period of ageing, the less the need for stimulation, although generally ES and ageing tend to be partly additive;
- carcase weight and fat thickness - heavier fatter carcases will tend to cool at a slower rate and therefore require less, or in some cases no, ES.

The requirement for ES will therefore vary between groups of cattle and even between individual animals. If there are other electrical inputs on the slaughter floor and/or the product will be vacuum-packaged and aged, the duration of ELV stimulation may need to be considerably less than the recommended 40 seconds, while in some cases, stimulation may not be required. With hot boning, ES is likely to be necessary, as it is essential that an accelerated rate of pH decline be achieved.

Measuring muscle pH and temperature as the beef side enters the chiller will indicate the effect of the combined electrical inputs. As a guide, if the pH is at or below 6.0 while the temperature is at, or above 35°C, then the electrical inputs have been excessive and there may be heat shortening. Subsequent pH and temperature measurements will indicate whether cold shortening is a possibility. If at any time the pH is at or above 6.0 when the temperature is at or below 12°C, then it is likely that the combined electrical inputs are insufficient and there may be cold shortening. These pH and temperature values are currently those incorporated in the Meat Standards Australia 'window' which is under review.

Minimising shortening by mechanical methods

Tenderstretch and Tendercut

Electrical stimulation prevents cold shortening by accelerating the onset of rigor mortis whilst the muscle temperature remains above the critical threshold of 12°C. Mechanical methods (Tenderstretch - see Australian Meat Technology (AMT) *Meat Technology Update* Newsletter No. 98/2 - and Tendercut) are also applied on the hot beef side, but prevent cold shortening by restraining the muscles during the rigor process. In the Tenderstretch process, hot sides are hung from the sacro-sciatic ligament or from the pelvis to increase the tension on the *longissimus dorsi* and some of the hindlimb muscles (Figure 2). In the Tendercut process, a similar tension on the muscles is produced by breaking the vertebrae and pelvic bones in the hot carcase. The Tendercut process overcomes some of the concerns of Tenderstretching, particularly the problems of sides breaking the pelvic bone or the sacro-sciatic ligament and dropping, the extra chiller space required, and the possible need to rehang Tenderstretch sides prior to boning.

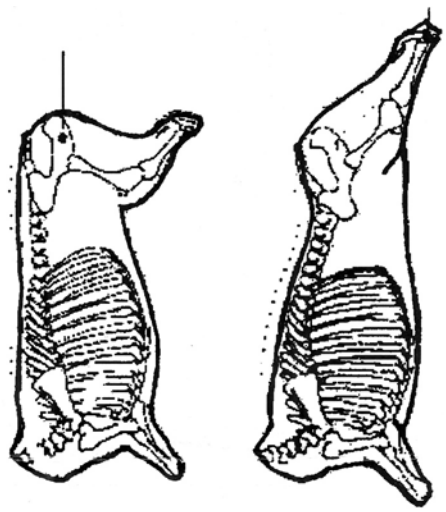

FIGURE 2 The shape of normally hung and Tenderstretch sides

Comparisons between conventional Achilles tendon (AT) hung carcases and Tenderstretch (TS) carcases indicate that TS reduces the ageing period necessary to reach a given level of eating quality. For the same ageing period, muscles from TS carcases are likely to be more tender than those from AT, although it should be noted that TS improves the tenderness of only some of the muscles on the carcase (see Table 1).

The Meat Standards Australia (MSA) system is based on an assigned eating quality score (the higher the score the better the eating quality) and uses three grades. In order of increasing score the grades are: MSA Tenderness Guaranteed, MSA Premium Tenderness and MSA Supreme Tenderness. An example of the possible scores and grades for various cuts is given in the Table 1.

Ageing

Most of the improvement with ageing occurs at 0-2°C in the first 7-10 days with only minor improvements developing with further storage. Ageing of meat on the carcase for more than a few days is usually impractical and meat is normally aged as vacuum-packaged cuts. The improvement in tenderness brought about by ageing meat on the carcase or in a vacuum bag is the same and is due to the breakdown of structural muscle proteins by enzymes. These enzymes have comparatively little effect on connective tissue and therefore prolonged (greater than 14 days) ageing periods may be necessary to improve the tenderness of cuts with higher connective tissue contents, such as the blade. The striploin is a low connective tissue cut and there is a more rapid improvement in eating quality with ageing (Figure 3).

It is possible that 'overstimulation' makes the enzymes less effective and thus electrical inputs should always be monitored to obtain the optimal rate of pH fall (see Figure 1). If the correct electrical inputs are applied to the carcase on the slaughter floor, then ageing and ES are likely to have an additive effect on tenderness. If severe cold shortening has occurred, then there may be only a minor improvement in tenderness with ageing. Improvements in tenderness following ageing occur more rapidly in meat that is tenderstretched than in that which is conventionally hung.

Meat is normally stored at 0-2°C during ageing. Higher temperatures will increase

TABLE 1 MSA eating quality scores and grades for 14-day aged cuts from Achilles hung and Tenderstretch carcases.

	Achilles tendon (AT)		Tenderstretch (TS)	
	Score	Grade	Score	Grade
Grilling cuts				
Rump	54	Tenderness Guaranteed	62	Tenderness Guaranteed
Striploin	62	Tenderness Guaranteed	67	Premium Tenderness
Cube roll	67	Premium Tenderness	68	Premium Tenderness
Blade	58	Tenderness Guaranteed	58	Tenderness Guaranteed
Tenderloin	79	Supreme Tenderness	76	Premium Tenderness
Roasting cuts				
Outside flat	42	Fails to grade	47	Tenderness Guaranteed
Topside	45	Fails to grade	52	Tenderness Guaranteed
Knuckle	62	Tenderness Guaranteed	64	Premium Tenderness

The values in the above Table are derived from a model in which the animals and carcases are assumed to have certain specifications. The animal specifications are: male, grass-fed with zero *Bos Indicus* content. Carcase specifications include; weight 240 kg, ossification score 150, ultimate pH 5.5.

Note from the eating quality score that the forequarter cuts (cube roll, blade) are not improved by the TS process and there is a slight decrease in the eating quality of the tenderloin (although it still grades as Premium Tenderness).

the rate of improvement but may have undesirable effects on subsequent storage life, retail display life, flavour and weep.

Other methods

A procedure, called the Rinsing & Chilling Technique (R&CT), which involves the intra-arterial infusion of a cold solution of electrolytes and sugars at exsanguination, has been used for some considerable time in the Americas to ensure tenderness. More recently, it has been used on Australian domestic beef. The procedure results in a very rapid pH decrease in muscles.

R&CT appears to be a potential technique to prevent shortening and toughening in hot-boned meat.

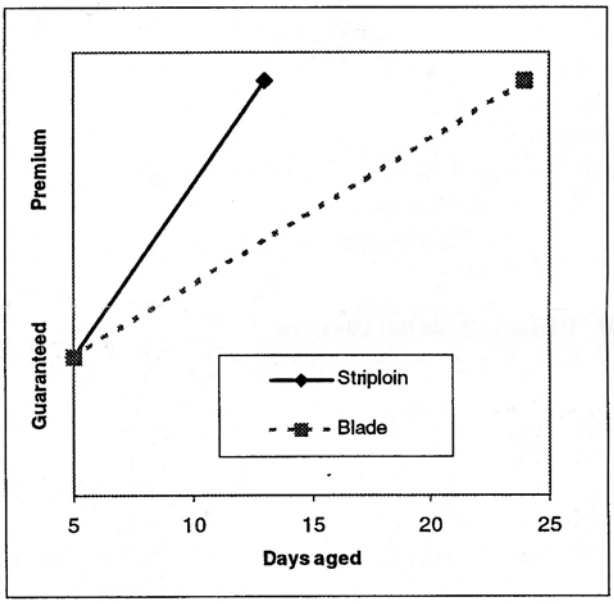

FIGURE 3 Estimated ageing period required to increase MSA grade of striploin and blade

Acknowledgements

The assistance of the following organisations in producing this newsletter is gratefully acknowledged:

- The Cooperative Research Centre for the Cattle and Beef Industry (Meat Quality)
- Meat Standards Australia

Contact us for additional information

Meat Industry Services is supported by the Australian Meat Processor Corporation (AMPC) and Meat & Livestock Australia (MLA).

Brisbane:
Food Science Australia
PO Box 3312
Tingalpa DC QLD 4173

Ian Eustace
T +61 7 3214 2117
F +61 7 3214 2103
M 0414 336 724

Neil McPhail
T +61 7 3214 211
F +61 7 3214 2103
M 0414 336 907

Alison Small
T +61 7 3214 2109
F +61 7 3214 2103
M 0409 819 998

Sydney:
Bill Spooncer
PO Box 181
KURMOND NSW 2757
T +61 2 4567 7952
F +61 2 4567 8952
M 0414 648 387

Adelaide:
Chris Sentance
PO Box 178
FLAGSTAFF HILL SA 5159
T +61 8 370 7466
F +61 8 8370 7566
M 0419 944 022

MEAT TECHNOLOGY UPDATE

Cutting edge technology for the meat processing industry