Meat technology update

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A Critical Control Point approach to beef eating quality

The production of beef that satisfies or, better still, exceeds the consumer's expectations with regard to eating quality is central to the industry's future.

The purpose of this update is to provide an overview of beef eating quality and the critical control points in any production pathway that can impact on quality.

Eating quality

Eating quality is determined by the consumer's perception of whether the product was:

1. Tender or tough
2. Juicy or dry
3. Flavoursome or lacking in flavour and free from taints.

Most of the research effort has been dedicated to the improvement of beef tenderness, as consumers have clearly said that the variation in tenderness/ toughness is the major factor limiting eating quality. In the future, as the variation in toughness is successfully reduced, it is anticipated that issues such as flavour will take on greater prominence.

Tenderness/toughness

The variation in tenderness/toughness can be partitioned into the muscle-fibre and connective-tissue components. In living muscle, the fibres are responsible for contraction. The action of the contraction is then transferred through the connective tissue framework of the muscle to the ligaments and tendons which attach to the skeleton. After death, muscle-fibre contraction and relaxation continues until the biochemical reactions underpinning this process cease. At this point, the fibres are irreversibly bound. This loss of extensibility is referred to as rigor. The degree of muscle-fibre shortening that occurs after death is the most important factor governing overall tenderness/toughness in cuts low in connective tissue (e.g. striploin). This, in turn, is regulated by the rates of pH decline and cooling in the muscle. The indicative relationships between pH and temperature decline and the degree of shortening are shown in Table 1.

Another process that impinges on the magnitude of muscle-fibre toughness is the enzymatic breakdown of some of the muscle-fibre proteins, which occurs when meat is aged. This is referred to as proteolysis and is controlled by a number of enzyme systems. Of these, the calcium-dependent calpains and their inhibitor, calpastatin, and the lysosomal cathepsins are considered the most important.

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TABLE 1: Indicative relationships between pH and temperature decline on post-mortem muscle-fibre contraction

pH	Temperature °C	Percentage of shortening#	Effect
≤6.0	12-20	10-20	Optimal for tenderness
>6.0 (slow)	<12 (fast)	30-50	Extremely tough (*cold shortened*)
<5.9 (fast)	>30 (slow)	20-30	Some loss in tenderness and possibly juiciness (*heat shortened*)

 # Relative to approximate resting length

The contribution of connective tissue to overall toughness depends on both its quantity and quality. The amount of connective tissue varies between muscles and this is a reflection of muscle function. For instance, muscles involved in movement contain higher amounts of connective tissue than muscles used to maintain posture. Connective tissue toughness occurs in proportion to the presence of heat-stable crosslinks within the connective tissue. Since the proportion of crosslinks increases with age, so does the connective tissue toughness.

Critical Control Points

To deliver beef of consistent eating quality, it is important to recognise that tenderness can be influenced at any point along the production pathway right up to and including the final process of cooking. In view of this, the Meat Standards Australia (MSA) system has targeted critical control points within production pathways and implemented specifications or practices which ensure that losses in eating quality are minimised.

The critical control points, key factors within each, and the association or effect they can have on the intrinsic muscle attributes are presented in Table 2.

Pre- and post-slaughter factors

The management of the animals and their carcasses in the 24–48 hours immediately prior to and after death has the greatest influence on ultimate eating quality. Inappropriate management during this phase can result in irreversible losses in eating quality.

Since complete coverage is not possible in this update, only a brief overview is given. More detailed discussion of pre-slaughter management of cattle and post-slaughter best practice will be the subjects of future updates.

Pre-slaughter stress must be minimised during the marketing of animals to slaughter. Stress results in losses in muscle glycogen. Sustained stress and/or muscular activity which results in the loss of >30% of the glycogen reserves in a normal, healthy animal will result in meat with a higher ultimate pH (≥5.9), increased toughness and reduced shelf life. This meat is typically referred to as ‘dark, firm and dry’ (DFD).

There is new evidence which suggests that acute stress immediately pre-slaughter or stress of a more subtle nature could be implicated in altering the rates of post-mortem pH decline and proteolysis. This area is currently being investigated by the Cooperative Research Centre (CRC) for the Cattle and Beef Industry (Meat Quality) and positive results have been achieved already by varying pre-slaughter management strategies.

Post-slaughter best practice is targeted at both minimising the degree of muscle-fibre contraction and ensuring optimal activity of the proteolytic enzymes. Minimising the degree of shortening can be achieved by ensuring the muscle enters rigor at an optimal pH and temperature (refer Table 1) or by restricting the fibres from shortening by stretching or restraining the muscle. The rate and extent of pH and temperature decline also influences post-mortem proteolysis. However, the nature of this relationship is less clear and is the subject of current investigations.

TABLE 2: Critical control points and associations with muscle characteristics

Critical Control Point	Factor	Tenderness					Juiciness	Flavour
		Muscle fibre shortening	***Ultimate pH (normal ≤5.7)***	***Rate of pH decline***	***Rate and extent of proteolysis***	***Connective tissue contribution***		
On-farm	Breed	✓		✓?	✓✓	✓✓		✓?*
	Environment/nutrition	✓✓	✓✓	✓✓	✓?	✓✓	✓	✓✓✓*
	Age/weight at slaughter	✓✓	✓	✓?	✓?	✓✓✓	✓	✓*
Pre-slaughter	Method of marketing		✓✓	✓?	✓?		✓	
	Time off feed		✓	✓?	✓?		✓	
	Lairage management		✓✓✓	✓?	✓?		✓	✓?
	Weather conditions (extremes)		✓✓✓				✓	
Slaughter	Stunning			✓				
	Electrical inputs#	✓✓✓		✓✓✓	✓✓		✓✓	✓?
	Method of carcass hanging	✓✓✓					✓✓	
	Duration prior to chilling			✓				
	Rate of chilling	✓✓✓		✓✓	✓		✓✓	
Process-ing	Ageing				✓✓✓	✓?	✓	✓✓
	Cooking method/ duration					✓✓✓	✓✓✓	✓✓✓

\# 'Electrical inputs' includes electrical stimulation, immobilisation, and stiffening during hide pulling
* The association between on-farm factors and flavour is primarily related to the amount, distribution and composition of fat within the meat
✓ Some influence
✓✓ Moderate influence
✓✓✓ High influence
? No conclusive evidence, but intuitively, it is reasonable to suggest an association.

With respect to minimising muscle-fibre shortening, the processor has three basic options:

1. Apply electrical inputs such as stimulation in conjunction with rapid chilling, immobilisation which may be carried out after stunning, and stiffening during downward hide pulling. These inputs accelerate pH decline and must be carefully monitored.
2. Use alternative carcass hanging treatments (prevents the myofibrils from contracting), e.g.
    - Tenderstretch (refer Meat Technology Update 98/2)
    - Tendercut®
3. Effective chiller management (achieve a moderate rate of cooling; however, this is not always practical from a food safety point of view).

The full benefits of either electrical inputs or alternative hanging treatments will be realised only when they are used in conjunction with fast chilling rates. Electrical stimulation may not always be appropriate for heavy carcasses.

On-farm factors

The primary on-farm factors include:

1. Breed
2. Weight and age at slaughter

3. Nutrition/production system.

Of all the critical control points, the on-farm factors have provoked, and continue to provoke, the greatest amount of controversy. Unfortunately, much of the debate has been unnecessary, as the magnitude of any effect has often been overestimated because the post-slaughter conditions were not controlled. For example, differences in weight and fatness, which typically occur between breeds (e.g. early versus late maturing breeds), and different finishing systems (e.g. feedlot versus pasture finishing) will give rise to differences in carcass cooling rates. In the absence of electrical inputs or alternative hanging treatments and when rapid chilling is used, these differences in cooling rates will cause variation in the degree of muscle-fibre contraction and thus, tenderness.

CRC and MSA results have demonstrated that, once the post-slaughter variation in eating quality has been controlled, any breed effect is quite small. That said, there are noticeable breed effects in tenderness and these are most evident when the *Bos indicus* content exceeds 75%. The exact reasons for this are linked to a number of intrinsic muscle factors; however, reduced proteolysis (i.e. ageing potential) has been demonstrated as a primary mechanism.

The age of an animal at slaughter is particularly important in the context of connective tissue toughness. Currently, MSA require that all eligible cattle are less than 30 months of age. MSA have also developed a specification, defined as 'weight at maturity' (WAM), which is a crude estimate of the growth rate/path.

With regard to beef flavour, on-farm factors are also important. Decisions that influence either the feed type (e.g. pasture species and grain ration content) and/or carcass fatness (amount and composition) impact on beef flavour.

Other processing factors

Ageing meat, either 'on the bone' or as vacuum-packaged cuts at storage temperatures of 0-2°C, improves meat tenderness. The magnitude and rate of improvement will depend on the post-slaughter management of the carcasses, the storage temperature and the ageing duration. For example, tenderness improvements following ageing will be smaller in magnitude following effective electrical stimulation and/or tenderstretching compared with normally hung, non-stimulated beef. The longer beef is aged, the larger the improvement; however, the majority of change occurs within the first seven days after slaughter. Ageing meat at higher temperatures will also increase the rate of improvement; this may, however, also compromise shelf life, flavour and weep.

Cooking is the final act in the process and it can have the largest effect on eating quality. Over-cooking or mismatching of the cut with the appropriate cooking method can result in significant consumer dissatisfaction. Consumer education is one way in which the chance of failure in the household can be avoided. Against this, however, is the issue of 'convenience culture' which distinguishes the modern-day consumer. Consumers not only lack the traditional meat preparation skills but, more importantly, they lack the time to prepare meals. Unfortunately, it is unlikely that this will change in the near future.

This represents an opportunity for the Australian beef industry through the application of value adding. The adoption of value adding technologies will enable the production of a wide range of pre-prepared, flavour-enhanced, ready-to-eat beef meal solutions. Benefits associated with this approach include the delivery of:

1. Consistent eating quality

2. Convenient beef products which match the tastes and health requirements of consumers

3. Ultimately, more competitive beef products.

This concept underpins the next stage for MSA, which aims at grading and labelling cuts in ways which reflect their end use. This not only expands the application of MSA to more than just the high value primal cuts (e.g. striploin, cube roll, tenderloin and rump), but it will ultimately obviate the need for some of the current pathway specifications, particularly the on-farm factors. For example, issues such as breed and growth history are not likely to have a large effect if the primal cut is to be minced, blended, flavour enhanced and pre-cooked prior to retailing.

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Contact us for additional information

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