Post farm-gate factors affecting the quality of grain-fed beef

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Introduction

We can all appreciate the importance of the chef to the enjoyment of a beef meal but correct processing at the abattoir is just as important as cooking. A top quality steer can produce a tough or dry-tasting steak as a result of poor chilling or too much electrical stimulation.

The customers of Australian grain-fed beef demand a variety of product specifications. Consumers rate the tenderness trait highly and research has confirmed the effect of processing inputs such as electrical stimulation, rate of chilling and ageing of meat on this aspect of quality. Meat colour, fat colour and marbling are also considered by customers in the decision to purchase. Some of the post-slaughter factors that affect meat quality interact with pre-slaughter factors such as nutrition, handling, and transportation. One of the most obvious post-slaughter conditions for which there is a strong pre-slaughter causative factor is the incidence of high ultimate pH and consequent "dark cutting".

The aim of this paper is to reinforce the need to manage all sectors in the beef production chain, including beef processing, to maintain and even enhance the inherent quality of product after the grain feeding phase.

How ultimate pH Affects Eating Quality

Ultimate pH affects the proportion of carcases assigned to MSA grades by consumer panels (Table 1). The higher the ultimate pH, the more failed to grade as satisfactory. Based on this data a cut-off of 5.7 was included in the specifications for the MSA grading system.

Table 1. Impact of ultimate pH on MSA consumer sensory scores

pH	failed	3 star	4 star
5.7 or less	20%	40%	40%
5.7 – 5.8	41%	31%	28%
> 5.8	54%	27%	19%

NB: This table considers only pH, it does not include other factors that affect eating quality.

Further research has also included ultimate pH as a variable input into the MSA cuts-based grading system. Once the acceptable level of ultimate pH has been met (pH 5.7) further improvement to eating quality and grading performance can be obtained by further lowering the pH to 5.4 (Table 2).

Table 2. Effect of ultimate pH on palatability (CMQ4) score of the chuck.

pH	*Chuck CMQ4 (max.100)*
5.4	57
5.7	54

High pH meat is also unsuitable for vacuum packing for ageing or storage, as it is more prone to bacterial attack and spoilage. High pH meat has a higher water holding capacity, which means that when cooked it won't release moisture to make the meat juicy, often making the meat dry, tough and chewy after cooking.

The Visual Impact

High pH meat is normally associated with dark meat colour. Generally the higher the ultimate pH, the darker the meat colour. Meat with AUS-MEAT colour of greater than 3 is known as a "dark cutter" and usually not preferred by consumers.

What causes high ultimate pH

When an animal is slaughtered, brain function and circulation are stopped but muscle continues to metabolise energy (known as glycolysis). The process of glycolysis produces lactic acid and energy that causes pH to decline. At approximately 8 to 10 hours the pH decline ceases, reaching the ultimate pH, ideally 5.3 to 5.7.

Glycogen and ultimate pH: The amount of energy stored as glycogen in muscle affects the ultimate pH. If there is only a small amount of muscle glycogen present pre-slaughter, then only a small amount of lactic acid can be formed, which may not be enough to reduce the pH of 7.2 down to the required range. Figure 1 shows that an ultimate pH of 5.7 or higher only occurs if the reserves of glycogen have been heavily depleted.

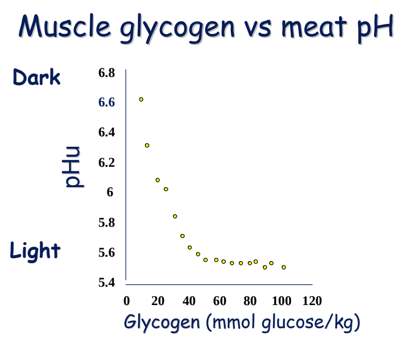
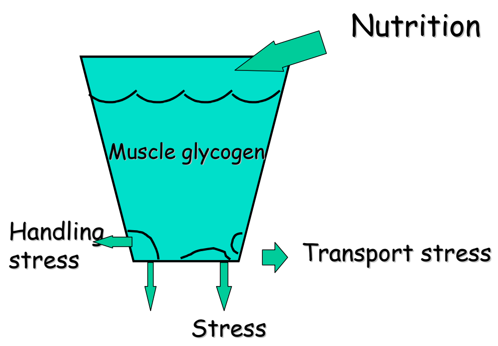


Figure 1. The relationship between ultimate pH and the concentration of glycogen in muscle post slaughter (Pethick et al, 1998).

What is glycogen? Glycogen is defined as "the store of body sugar". In the muscle glycogen is an important reserve of potential energy. The storage system for glycogen in cattle can be likened to a "bucket". Nutrition replenishes the store. Various stresses cause leakage from the bucket. To avoid high ultimate pH, or dark cutting beef, you need to keep the bucket topped up, and reduce the leakages.



Avoiding the risk of "dark-cutting" beef.

Dark-cutting beef (DCB) is a significant loss in the processing of beef and is largely a loss attributed to poor handling and nutrition. In the beef carcase, DCB occurs when a cut surface of meat fails to brighten when exposed to oxygen. DCB is accompanied most often by a high ultimate pH of 5.8 or above. Meat with a high pH will in addition to being dark, be firm and dry.

Slaughter data collected in recent years suggest that the commercial incidence of DCB in Australia is in the order of 8-10% with an economic loss of over $38m (Walker,1997). More recent data from domestic beef carcasses graded under MSA indicated an annual incidence of 6.7% for DCB (Beer, unpublished). MSA best practice guidelines for pre-slaughter delivery of cattle indicates that additional factors are contributing to the incidence of DCB.

Importantly, no single management change for the lotfeeder or processor will entirely prevent dark cutting. A number of management strategies must be used collectively to reduce the risk.

An example of strategies include:

- Varying the season of **turn-off** for pasture fed steers to **spring or autumn** rather than winter when glycogen levels may be lower (+15% glycogen)
- Intensively **feeding** on **grain** for a minimum 2 weeks (+23% glycogen)
- **Directly consigning** them to slaughter (+7% glycogen)
- **Minimal lairage** handling regimen (+11% glycogen)

A combination of strategies may assist in increasing or maintaining muscle glycogen content at slaughter.

Strategies for eliminating high pH and meat colour

The key considerations for ensuring the requirements for pH and meat colour are met include:

- Growth rate
- Seasonal conditions
- Feed type (eg. Grain vs grass)
- ME dietary content
- Fat cover
- Curfew periods

Growth rate – cattle should not be slaughtered on a declining plane of nutrition or with an ADG of less than 0.5 kg/day.

Feed type – cattle fed grain and silage diets typically have higher muscle glycogen concentrations than those on pasture or those fed pasture hay. This provides a buffer against "leakage" but does not discount the need for careful handling. Cattle on maize and barley diets have shown a greater glycogen loss after a period of exercise but replenish body reserves at a faster rate than those on a diet of hay.

Feed quality (ME) – The predominant effect feed type has on initial and post stress glycogen concentrations is related to the metabolisable energy (ME) content of the diet.

Seasonal conditions – In Australia muscle glycogen is at critically low concentrations in winter and summer, corresponding with periods of low pasture availability and quality. Grain feeding cattle will help avoid this, but animals on low ME diets (eg. silage and pasture) may still be susceptible. Loss of glycogen due to seasonal conditions such as cold+wind+rain is common to all cattle.

Fat cover –. Cattle with high fat levels do not seem to be at a lower risk of dark cutting compared to lean cattle. Adequate fat levels should not be used as the sole indicator of glycogen levels.

Curfew periods – lengthy pre-trucking curfews should be avoided. In steers fasted for 92 hours glycogen levels were reduced by 35%, increasing the risk of high pH.

Glycogen deficiency cannot be assessed from the appearance of the animal. The background treatment and feeding program is critical.

There are a number of other strategies that can assist in minimising the risk of "dark cutters".

- Isolate "at risk" animals such as heifers in oestrus and stock off poor nutrition.
- Minimise the lairage and transport time.
- Avoid mixing stock from different pens prior to slaughter.

Beef tenderness and processing

Let's take a brief look at what happens to muscle just after slaughter.

- The muscle continues to function in terms of contraction and relaxation.
- Glycolysis produces energy (ATP) from the muscle store of glycogen to enable relaxation.
- Lactic acid produced by glycolysis causes pH to drop.
- Rigor mortis usually occurs at about pH 6.0. The degree of muscle contraction at this point is very dependent on temperature.
- pH continues dropping until ultimate pH is reached, but the rate at which pH drops, and the temperature at which pH 6.00 is reached, can affect eating quality.

It is important that ultimate pH is not confused with pH/temperature decline because it too contributes to developing toughness.

pH/Temperature Decline

The different patterns of pH decline with relation to temperature decline are shown in Figure 3. If muscle cools too quickly, a condition known as **"cold shortening"** can occur. In this situation, the degree of contraction is considerable when the temperature falls **below 15°C** while the **pH** is still **>6.0**. This is irreversible and can result in a **threefold increase in toughness**.

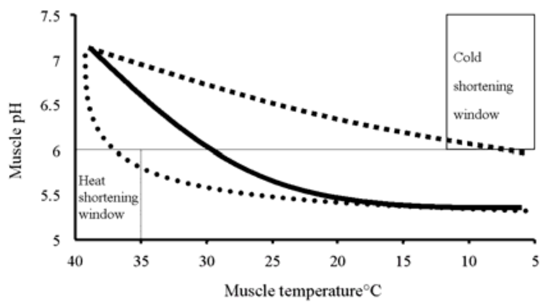


Figure 3. Muscle pH & temperature decline post slaughter for beef carcases

Processors can overcome cold shortening by:

- Appropriate chiller management.
- Electrical stimulation – low voltage (45V), high voltage (800V)
- Tenderstretch carcase hanging.

Abattoir audits of the pH/temperature window found that many abattoirs were effectively over-stimulating, with carcases entering the **"heat shortening"** region (ie achieving **pH 6** at temperatures **greater than 35°C**). This is due in part to other electrical inputs on the slaughter chain, eg. immobilisers, rigidity probes that, along with electrical stimulation, accelerate glycolytic rate.

A benchmarking study by the beef CRC (Daly et al 2002) showed that post-mortem glycolytic rate in the carcase was a function of glycogen concentration within the muscles, ie the energy store an animal had at the time of slaughter. The primary implication of this relationship is that carcases with low glycogen concentrations will need more electrical stimulation in order to achieve optimum rates of post-mortem glycolysis and reach pH 6 at an optimum temperature, whilst carcases with higher glycogen levels, such as grainfed cattle, will require less stimulation.

The recommendations for abattoirs include:

- Cattle with high reserves of glycogen, such as lot fed cattle, require less electrical stimulation,
- Lighter, leaner carcases, such as domestic trade, are the most susceptible to cold shortening,
- Heavier, fatter carcases as destined for the export trade tend to cool more slowly and therefore require less, or nil electrical stimulation.

Other Meat Quality Traits

Fat colour

The major fat soluble compound that accumulates and causes yellow fat is ß-carotene. The transfer of cattle from fresh pasture to a grain diet reduces the ß-carotene concentration in blood serum and the fat will not continue to increase in yellowness. It is unclear, however, whether the carotene is removed from solution in the fat or diluted out as the animal grows.

Marbling

As fat cools from the melted or liquid state (live animal at about 40°C) it undergoes a series of transformations with major phase transitions occurring at about 8 –15°C and also at about 35 – 40°C. These changes affect the reflection of light and the fat appears more opaque. At chiller temperatures of around 10°C, the appearance (or opaqueness) of the fat will depend on the proportion of the fat that has undergone the phase transition. In meat where the marbling fat is more unsaturated, and where there is incomplete transition, the fat will be partly translucent (less white) and will not appear boldly against the red muscle background (Tume 2001). Under these conditions, chiller assessment of marbling would result in a lower marbling score than where the fat is more saturated.

It is imperative that marbling assessment is performed on carcases at as low a temperature as possible. Carcase chilling procedures are usually a compromise between food safety requirements and the boning problems associated with hard carcase fat. It is common practice to chill to a loin temperature of about 5°C at 20 hours and then to commence carcase rewarming for about 3 hours to minimise the hard fat problem.

The importance of temperature on visual assessment of marble score is illustrated by the work of Pethick et al. (1997). 107 carcases were assessed under commercial conditions (day after slaughter, carcase temperature 11-12°C) and then re-assessed 24 hours later at 5°C. At initial assessment, only 41 carcases achieved a marbling score of >2 whereas after a further 24 hours with chilling to 5°C, 51% had scores of >2.

Dietary effects on fat hardness

Japanese markets are demanding product with increased marbling but also with softer fat. Whilst the industry appears to be moving towards producing softer fat, which also has benefits for carcase boners, there are negative implications for marbling as measured in Australia. Feeding systems that enhance the softness or unsaturation of fat may lead to a reduction in the stearic acid content of intramuscular fat, which will make the marbling more translucent and less visible, as described above (Tume, 2001). However it is not possible to categorically state that one finishing system or diet leads to a more saturated fat or a particular fatty acid composition, although there is considerable anecdotal evidence that feeding whole cottonseed can result in hard carcase fat, with higher levels of stearic acid.

A CRC trial (Kelly 1999) found that the content of trans-fatty acids in fat was not only higher in grain-fed compared with pasture-fed cattle, but was significantly higher for cattle finished in northern, compared with southern, locations. It is likely that the high proportion of trans-fatty acids resulted from inclusions of plant oils in the diets.

Seasonal and climatic variation

Seasonal and climatic changes in fatty acid composition can occur in beef carcases. Temperature and rainfall are likely to affect fatty acid composition in several ways. Firstly, there may be differences in feeds (or feed quality) from one season to another, although that is likely to be more of an issue for pasture-fed rather than grain-fed cattle. Secondly, changes in fat composition result from established climatic differences (colder versus warmer regions). Differences resulting from direct temperature effects are most likely to occur only in subcutaneous fat as the deeper depots are insulated from temperature change. For grain-fed cattle essentially no variation in stearic acid would be expected for the more deeply located marbling fat.

Take home messages

- Good nutrition is essential to prevent high ultimate pH and consequent dark-cutting and reduction in tenderness.
- Grain-fed animals should therefore be less prone to dark cutting.
- Grain fed carcases may not need electrical stimulation if they are also heavy and fat.
- Grain fed carcases have whiter fat than grass fed carcases
- The softness (saturation) of fat on grain fed carcases may be manipulated by diet.

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