The following pages include practical information that the Sheep CRC has developed from the scientific research carried out during 2007–2014.

It is intended as a source of information to help the Sheep Industry put into practice some of these new ideas.
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Achieving a brilliant finish to your lambs

Key points

- Lamb finishing strategies and curfew management can affect producer returns, carcase traits and meat quality.
- Vitamin E supplements for two to four weeks prior to slaughter can improve shelf life.
- Magnesium Oxide supplements for only four days prior to slaughter can reduce the effects of stress on glycogen reserves and may be particularly useful when finishing Merino lambs.
- Feeding high quality diets for 14 days pre-slaughter to ensure weight gain can improve meat qualities such as juiciness and tenderness.
- Curfew periods should not exceed 24 hours.
- Ensuring lambs have access to and experience with water troughs will help reduce carcase weight loss.
- Total time off feed prior to slaughter should not exceed 48 hours.

Introduction

Building year round demand for lamb meat requires that consumer acceptance is addressed. The finishing and curfew strategies that you choose can influence carcase traits and the meat quality of your lambs. Optimizing management of the finishing and curfew periods is important for lamb meat value and returns.

How can changes to the finishing diet influence meat quality?

The diet of a lamb has an important influence on meat quality and consumer acceptance. Often only short feeding periods are required to remedy a dietary deficiency that might have occurred under paddock conditions. Feeding supplements late in the finishing period Image courtesy MLA is often all that is required to improve consumer acceptance.
Energy

Lambs need to be growing during the finishing period. This ensures that energy intake is sufficient to keep muscle glycogen reserves at a level that is adequate for premium meat quality. If lambs are losing weight in the paddock, then muscle glycogen reserves can be boosted by feeding a good quality diet for about 14 days prior to slaughter. A diet with an energy level of 10 to 11MJ/kg (Megajoules per kilogram of Dry Matter) is sufficient to boost muscle glycogen concentration when fed ad libitum. Excessively high energy diets, particularly those that contain high levels of wheat, may cause lambs to scour and the meat to have off flavours and soft fat. Scouring can cause soiling of skins in the feedlot and during transport. These factors should be considered, as well as growth rate, when formulating feedlot ration.

Roughage

If lambs have been scouring when grazing green pasture, feeding hay just prior to consignment can improve faecal consistency and reduce food safety risks. This can be done prior to curfew but should be restricted to a maximum period of two days. Feeding high roughage diets for longer than two days can lead to weight loss, low muscle glycogen concentrations and reductions in meat eating quality. Ideally, lambs should be growing at the time of slaughter. High roughage diets can reduce dressing percentage and increase effluent output from traveling livestock. Lambs eating highly digestible feedlot type diets tend to produce less effluent during transport.

Reducing carcase fat

Restricting feed intake and quality to reduce fat and achieve a lower fat score is not recommended during the finishing period. Eating quality can be reduced, in particular the juiciness of the lamb meat when applied for a period of 10 days or more before slaughter. Figure 1 shows the difference in juiciness of lambs fed different diets pre-slaughter. Lambs fed straw were less juicy than lambs fed diets adequate in energy.

Feed additives

Magnesium oxide

Stress during the transport and lairage period can cause a reduction in muscle glycogen concentration and predispose lambs to tough, dark cutting meat. This is particularly so for Merino lambs but less important for crossbred lambs. Whilst rations are rarely deficient in magnesium, addition of magnesium oxide to the finishing ration can help reduce the effect of stress on muscle glycogen reserves. However, this is not an alternative to, and should not be substituted for, good feed and management of
lambs. The recommended rate of addition of magnesium oxide to finishing rations is 1%. This should be added for four days only prior to slaughter. The value of this effect will be reduced if magnesium is fed for longer than this period of time.

**Vitamin E**

In southern Australia dry feed is often deficient in vitamin E and meat from lambs finished in the summer and autumn period can have reduced shelf life as a result. For lambs finished under dry feed conditions that have not been supplemented previously, the addition of vitamin E to the ration will restore meat vitamin E concentration to a level that is adequate for good shelf life. The recommended feeding rate for this is 250ppm for the last 2 to 4 weeks prior to slaughter. As well as improving shelf life, vitamin E supplementation causes meat to be lighter in colour, measured as a higher L value (Figure 2). Light meat tends to be more visually attractive to consumers than dark meat.
Salt and electrolytes

Using salt (sodium chloride) or electrolytes to rehydrate lambs or increase glycogen levels pre-slaughter is not recommended. High salt intake increases urine production, which causes soiling during transport. Experiments with commercial electrolyte replacement products during the curfew transport or lairage periods have failed to demonstrate any clear advantage.

Curfew management

The curfew period is the period on farm where the animals are off food and water prior to transport to reduce the risk of soiling. Delivering lambs that are clean at the time of slaughter is an important food safety requirement. However, care needs to be taken to ensure that food safety considerations do not adversely affect animal welfare, meat yield and meat quality.

Time off feed - Fasting is important for reducing gut contents prior to transport and slaughter. Soiling on trucks is both a food safety and an environmental issue. However, research has shown that most of the reduction in gut contents occurs within the first 24 hours of a fasting period. Little further benefit is gained by extending the fasting period beyond 24 hours.

Fasting reduces carcase weight and fat score, so curfew should be kept as short as practicable. Extending the curfew period to 48 hours can reduce carcase weight by up to 0.5 kg for a 20 kg lamb carcase (depending on fat score and other factors). The cost of this loss to the producer is $1.50 per lamb when the carcase value is $3.00 per kg. Total time off feed prior to slaughter should not exceed 48 hours regardless of the pathway.

Water troughs - Dehydration can also reduce carcase weight. Studies have shown that lambs sometimes fail to drink even when water is made available in lairage yards. If they do not drink after transport they will be dehydrated at slaughter. Dehydration will reduce carcase weight and can cause meat to appear darker in colour, and less appealing to the consumer. Providing lambs with water troughs during the finishing period is a way of educating them about the source of water in lairage yards.

Shearing - MSA guidelines recommend that lambs should have greater than 5mm of wool at the time of slaughter.
Take home messages

- Lamb finishing strategies and curfew management can affect producer returns and lamb meat quality.
- Cheap, short term supplementation with Vitamin E and Magnesium Oxide can improve shelf life and meat quality.
- Feeding high quality diets for 14 days prior to slaughter can improve juiciness and tenderness.
- Curfew periods should not exceed 24 hours and ensuring lambs have access and experience with trough water will help reduce carcase weight loss.
- Total time off feed should not exceed 48 hours.

Further information

For further information on shearing and time off feed the Tips and Tools: MSA Requirements for Handling Sheep can be found at: www.mla.com.au/TopicHierarchy/InformationCentre/TipsandTools/MSA/default.htm Visit www.sheepcrc.org.au to view more Practical Wisdom Notes.

Acknowledgements

This research was funded jointly by the Sheep CRC and Meat and Livestock Australia.
Achieving target pH and temperature declines to improve meat quality

Key points

- Optimising the rate of pH and temperature decline improves sheep meat eating quality. Meat Standards Australia (MSA) for Sheep Meat will require meat processors to measure and control systems to achieve the optimum pH-temperature window.

- To determine the proportion of carcases hitting the window, four times each year, processors should select and monitor four consignments with 25 carcases per consignment. pH should be recorded 20 to 30 minutes post slaughter and again when the carcase is close to 18°C.

Introduction

Recent work jointly funded by the Australian Sheep Industry Cooperative Research Centre (Sheep CRC) and Meat and Livestock Australia has found that the rate of pH and temperature decline of a carcase can significantly affect eating quality. The muscle pH of a carcase declines post-slaughter from 7.2 to about 5.5 due to the conversion of muscle glycogen to lactic acid. If the rate of pH decline is too slow (high pH at low carcase temperature), cold shortening may occur. Cold shortened meat is tough or even inedible.

The ideal window is the specification used to describe the relationship between pH and temperature fall during chilling and the objective is to manipulate pH fall so it passes through the window. Hitting the window can shorten the ageing time of meat to reach consumer acceptable tenderness, reduce the variation in tenderness and enhance meat colour. By boosting the perception of lamb in the market place and increasing overall lamb consumption, farmers, processors and consumers all benefit.

![Figure 1. pH-temperature decline in lambs](image)

Figure 1. pH-temperature decline in lambs
Processors participating in the Meat Standards Australia (MSA) program for Sheep Meat will be required to measure and control systems to achieve the pH-temperature window. The evidence says that sheep and lamb processors cannot hit the window without methods to either slow temperature decline or speed up pH decline. The former approach can compromise food safety; the latter can be achieved with electrical stimulation of the carcase.

**How is pH-temperature decline measured?**

The rate of decline is commonly expressed in terms of the temperature at which the loin muscle of the carcase reaches a pH of 6. Temperature and pH readings are taken at timed intervals using a combined pH/temperature meter during chilling. Using the standard location for measurement is very important: this is found at the lumbar-sacral junction and overlaying fat is cut away to prevent fouling of the pH electrode.

The data obtained is then used to calculate a rate of pH by temperature decline from which it is possible to predict the temperature at pH6.

**What are the new pH-temperature guidelines for sheep meat?**

MSA research has identified that for optimal eating quality of sheep meat destined for specific markets the targets in Table 1 should be met.

Table 1. pH-temperature guidelines for sheep meat.

<table>
<thead>
<tr>
<th>Ageing period</th>
<th>Hanging system</th>
<th>Required temperature @ pH6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short ageing period of 5 days (domestic product)</td>
<td>Achilles hung</td>
<td>18-35°C</td>
</tr>
<tr>
<td>Short ageing period of 5 days (domestic product)</td>
<td>Tender stretch/pelvic hung</td>
<td>8-35°C</td>
</tr>
<tr>
<td>Longer ageing period 10 days</td>
<td>Achilles hung</td>
<td>8-35°C</td>
</tr>
</tbody>
</table>

Figure 2. Measuring pH at the loin using a pH meter.
What compliance rates can be achieved?

Under commercial conditions there is considerable variation between carcases and it is difficult to get all carcases within the window. Results from abattoirs around Australia show that the percentage of carcases that can achieve a pH of 6 at 18 to 35°C, without electrical stimulation, is 15%. This will vary from plant to plant.

With the use of an optimal electrical stimulation setting this can be increased to over 80% depending on the chilling regime of the abattoir (Table 2). The pH-temperature range has expanded from the previous 18–25°C (Achilles hung, aged for 5 days), as recent research has suggested that it is possible to increase the maximum temperature to 35°C without any detriment to eating quality. This change will increase the number of animals that will meet the guidelines (in this example from 60% of carcases to 80%) with no cost to meat quality.

Reasons for non-compliance include animal variability, fast chilling rate, low muscle glycogen levels due to stress or poor nutrition pre-slaughter and variation in stimulation units between abattoirs.

Table 2. Percentage of carcases achieving pH-temperature guidelines.

<table>
<thead>
<tr>
<th>% of Carcases</th>
<th>Compliance</th>
<th>Non-compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pH 6 between 18-35°C</td>
<td>pH &lt;6 at 35°C</td>
</tr>
<tr>
<td>No stimulation</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Optimal setting for domestic market (2.5ms, 1A, 15Hz)</td>
<td>80</td>
<td>2</td>
</tr>
</tbody>
</table>

How are compliance rates audited?

Processors should independently audit their plants to determine compliance rates of carcases hitting the optimum pH-temperature window. If only a low percentage is achieved, then a number of alterations can be made including the use of electrical stimulation (which accelerates the rate of pH decline), varying the stimulation time and setting or adjusting the chilling regime.
The process of determining compliance rate is:

- Processors should randomly select 4 consignments per day that reflect the variation in carcases being processed over the day.
- Within each consignment 25 carcases should be measured (i.e. 100 sheep per day).
- The pH and temperature of each carcase should be recorded at 20 to 30 minutes post-slaughter (on entry to the chiller) and then again when the carcase is approximately 18°C).

This data should then be used to calculate the temperature at pH 6 using the following equation. The temperature should be in the range of 18 to 35°C for the carcase to hit the pH-temperature window.

\[
\text{Temp at pH6} = \text{TempA} - \frac{pHA - 6}{(pHA - pHB)/(TempA - TempB)}
\]

Where:

TempA and pHA represent the first temperature and pH measurement taken 20 to 30 minutes post-slaughter (usually above pH6).

TempB and pHB represent the measurement taken when the carcase is around 18°C (usually below) pH6).

- This process should be completed a minimum of 4 times per year and include a variety of seasons.
- To regularly test whether the stimulator is working, 5 carcases from each of 4 lots can be measured on entry to the chiller.
- Consultation with Sheep CRC researchers is possible to assist processors with data interpretation.
Take home messages

- Optimising the rate of pH and temperature decline improves sheep meat eating quality.
- Meat Standards Australia (MSA) will require meat processors to measure and control systems to achieve the pH-temperature window.
- Four times per year, processors should select four consignments per day and 25 carcases per consignment to determine the number of carcases hitting the window.
- pH should be recorded 20 to 30 minutes post slaughter and again when the carcase is close to 18oC.
- To regularly test whether the stimulator is working properly, five carcases from each of four lots can be measured on entry to the chiller.

Further information

For further information visit www.sheepcrc.org.au

Acknowledgements

This research was funded jointly by the Sheep CRC and Meat and Livestock Australia.
Bone growth and selection for muscling

Key points

- Selection for eye muscle growth (PEMD) decreases the length of the leg bones and specific sire selection for muscling may shorten the legs.
- Single trait selection for muscling may have the consequence of shrinking the skeletal frame and this underpins the need to use a multi trait selection approach.

Introduction

Work jointly funded by the Australian Sheep Industry Cooperative Research Centre (Sheep CRC) and Meat and Livestock Australia has highlighted the possible unintended consequences of single trait selection for muscling.

As a sheep grows from a lamb to an adult, its bones lengthen at special cartilage growth regions called growth plates. When these close and become converted to bone, growth virtually ceases and the animal is skeletally mature. Though this final fusion might not occur until the sheep is over three years old, length-wise bone growth has slowed to a trickle long before then. A sheep will reach 95% of its final mature leg length at around 1 to 1.5 years of age.

However, lamb growth involves more than just a simple increase in size. Different bones grow at different rates, resulting in changing leg proportions as the sheep matures from a gangly, long-legged lamb to a well-proportioned adult. This ‘skeletal’ maturation occurs in tandem with ‘physiological’ maturation, invisible changes such as altered enzyme and hormone levels that affect meat quality and carcase composition. The relationship between these two processes is not fully understood. The relationship between these two processes is not fully understood. Muscle growth sits somewhere in between the two, partly a physical process (longer bones mean longer, larger muscles) and partly a physiological process affected by the timing and relative development of muscle groups. The relative timing of bone, muscle and fat development is important because it creates what is loosely termed the ‘animal maturity type’ and is linked to carcase composition at slaughter age.
What does the research tell us?

Limb bone growth was compared in commercially relevant genotypes; Merino x Merino, Border Leicester sire x Merino, Poll Dorset sire x Merino; and second cross (Poll Dorset sire x Border Leicester/Merino ewe), from 4 to 22 months of age. Poll Dorset sires were selected for high Australian Sheep Breeding Values (ASBVs) for either growth (post weaning weight—PWWT) or muscling (eye muscle depth—PEMD).

The results showed often striking differences in bone growth between the genotypes, although these differences were more modest when compared allometrically, that is, the length or weight of individual bones relative to the whole of the leg. This confirms that the differences in bone growth between the genotypes were mostly secondary to a more generalised difference in the timing and rate of growth.

The results also showed:

- The leg bones of ewes were distinctly shorter than wethers by around 2 to 3% at 8 months and 8 to 9% as adults. In fact, this difference was much greater than the differences between any of the five genotypes. This is because hormones, principally oestrogen, cause the growth plates of ewes to close earlier.
- There were clear differences in bone size of Poll Dorset cross lambs from sires selected for muscling (PEMD) or growth (PWWT).
- Merinos had comparable adult leg length to terminal sire crosses, but with quite different proportions—longer lower leg (cannon and shank) and shorter upper leg. The lower muscle to bone ratio of Merinos is partly due to their ‘leggy’ proportions.
- Of all the leg bones, the cannon bone (metacarpal or metatarsal) is the most variable and least ‘controlled’ in its growth pattern. This means the use of the USDA ‘break joint’ specification as a maturity indicator is unreliable.
What were the differences in maturity type?

Comparing the bone length of growing animals to predicted adult lengths allowed estimation of skeletal maturity. This showed that in wethers, high muscling Poll Dorset and Border Leicester x Merino crosses matured faster than growth-selected Poll Dorset crosses and Merinos. Genotype differences at maturity were less for the earlier-maturing ewe lambs.

These patterns of skeletal maturity did not necessarily match with other observations of maturity such as permanent incisor eruption (two tooth eruption occurred earlier in Border Leicester crosses) or indicators of physiological maturity such as bone mineral and muscle enzyme profiles (which indicate muscling-selected Poll Dorset crosses were in fact less mature physiologically).

What are the implications of selecting for high muscling?

One possible unintended consequence of using sires identified as genetically superior for eye muscle growth (PEMD) to increase carcase muscling is highlighted. The leg bones of lambs from Poll Dorset sires with high ASBVs for PEMD were distinctly shorter than those from sires with high growth ASBVs, despite similar body weights. While this difference was greatest in the lower leg (cannon and shank), heavily-muscled bones such as the femur (thigh) and humerus (upper foreleg) were also 2 to 3% shorter.

Other production data showed that the carcases of high muscling lambs were also shorter along the spine, and had lower carcase bone percentage, suggesting this limb shortness may be indicative of generalised skeletal stunting in animals bred for high eye muscle depth. This parallels a similar phenomenon seen in double-muscled cattle. In trying to increase production through increased relative muscling, we must take care that we are not unintentionally shrinking the bony frame rather than increasing muscle. Selection for a single trait such as eye muscle depth can have unintended side effects, and underpins the need to use a multi-trait selection approach.
Take home messages

- Use a balanced multi-trait selection approach (such as with a Carcase Plus index) with emphasis on both muscling (EMD) and growth (WWT) to gain improvements in carcase size. This approach also has the benefit of maintaining good eating quality as carcse size increases.
- Single trait selection alone for high muscling without a balance with high growth can result in decreased length of the leg bones and may have the unintended consequence of shrinking the skeletal frame.
- The use of the USDA ‘break joint’ specification as a maturity indicator is unreliable and not recommended, because the cannon bone is the least ‘controlled’ bone in its growth pattern.

Further information

For further information visit www.sheepcrc.org.au

Acknowledgements

This research was funded jointly by the Sheep CRC and Meat and Livestock Australia and was conducted by staff of Murdoch University.
Intramuscular fat: The key to maintaining eating quality while improving lean meat yield

Key points

- Moderate levels of intramuscular fat (IMF) contribute strongly to lamb’s reputation for tenderness, juiciness, flavour and overall liking.
- Genetic selection heavily in favour of lean meat yield risks an unfavourable decline in IMF and therefore eating quality.
- Genetic selection can be tailored to maintain or improve both IMF and lean meat yield.

Introduction

While increased lean meat yield significantly improves processing returns and helps to meet consumer demand for lower fat sheep meat, the current genetic selection for components of yield potentially may have unfavourable effects on eating quality.

To achieve greater lean meat yield, rams have been selected with higher post weaning weight (PWT) and eye muscle depth (PEMD) Australian Sheep Breeding Values (ASBVs) and lower post weaning fat ASBV (PFAT). This has significantly increased lean meat yield over the last decade, particularly in the terminal sire breeds.

However, decreasing fat at the C site (the measurement site for post weaning fat) also lowers intramuscular fat (IMF), which in turn lowers the eating quality attributes. Intramuscular fat plays a major role in consumer perceptions of tenderness, juiciness, flavour and overall likeability of lamb, generally with a minimum of 4% intramuscular fat required to maintain positive consumer responses.

While the market signals for live weight or carcase weight are clear, those for lean meat yield, fat and eating quality characteristics are not, but this may change in the future as new technology to measure yield and eating quality becomes available.
Nevertheless, the interests of the lamb industry—that is to maintain the reputation of lamb as both a nutritious and flavoursome meat—will be best served by continuing to produce lean carcases while concurrently maintaining or improving eating quality, in particular the tenderness, flavour and juiciness of lamb.

The Sheep CRC Information Nucleus Flock produced lambs from terminal, maternal and Merino sires out of first cross and Merino ewes across eight sites for five years. Phenotypic and slaughter data on these lambs were collected allowing research into meat traits and analysis of these in relation to management, selection methods and eating quality.

While the results supported some of the findings of previous studies, new outcomes were also generated. The information and recommendations that follow are based on this research.

What affects intramuscular fat?

**PFAT and total carcase fatness**

Post weaning fat (PFAT) and intramuscular fat (IMF) are genetically correlated. Selection for lower PFAT decreased IMF in progeny of terminal sires, and at a lesser rate in Merino and maternal sires in the Information Nucleus Flock. It is likely that these breed differences may be due to the lower selection pressure traditionally applied to PFAT in maternals and Merinos.

In terms of measurements on the carcase, in particular, as shortloin fat decreased (and shortloin muscle increased) for carcases of similar weight, IMF decreased. However, while shortloin muscle and fat are good indicators of whole carcase muscle and fatness, this offered only a partial explanation for the decline in IMF.

Furthermore, the impact of PFAT on the eating quality, in particular tenderness, varies depending on the cut and partly its inherent level of IMF.

The loin had a greater decline in tenderness scores compared to the topside in progeny of sires with lower PFAT and this was partly explained by the different IMF levels. The decline in tenderness also varies depending on the cut and its inherent level of IMF, for instance, the loin has a greater decline in IMF compared to topside in progeny of sires with lower PFAT.
PEMD

Contrary to prior research, there is a low genetic correlation between post weaning eye muscle depth (PEMD) and IMF.

While the Information Nucleus Flock had a small number of extreme sires that did show high PEMD and reduced IMF, the remainder of the 279 sires showed no such relationship. Therefore, selection for both increased PEMD and IMF will be relatively straightforward.

However, independent of IMF, an increase in PEMD was associated with higher shear force and a decrease in the tenderness, overall liking and flavour scores in meat subject to consumer testing. However, given that IMF has a strong genetic correlation with reducing shear force (more tender), simultaneous selection for PEMD and IMF will be beneficial for consumers.

PWT

There is no genetic association between post weaning weight (PWT) and intramuscular fat.

Selection for higher PWT will increase growth rate and mature size and animals will reach slaughter weight earlier, but IMF is not affected.

As carcase weight increases (corrected for slaughter age), so does IMF, which shows the importance of growth rate driving IMF. This is likely to be a phenotypic relationship reflecting environmental effects on growth rate rather than a genetic effect related to mature size.

While extra nutrition to achieve heavier weights at slaughter could provide higher IMF levels, the effects are low compared to sire effects.

Other factors

Other management and production factors are likely to affect IMF. The study results were not conclusive for nutrition, dam genetics, slaughter age and the breed type of sires, but they may affect IMF. However, hot carcase weight was clearly shown to have the largest of the non-genetics effects on IMF, with higher weights having higher IMF. Increased fatness at the GR site was also associated with increased IMF, but the effect was minimal above fat score 3 (15mm).
Do Australian lambs have sufficient IMF?

The Information Nucleus Flock study is representative of the range of Australian production regions. While the average IMF% was just greater than the 4% minimum level for acceptability, a significant proportion of lambs fell below this level. Hence, this highlights the need to carefully monitor continued selection for lean meat yield to avoid lower IMF levels.

Can selection for lean meat yield continue while maintaining eating quality?

The development of the Sheep CRC genomics test has seen a number of new breeding values calculated for meat traits; these include lean meat yield and intramuscular fat ASBV, both of which have moderate to high heritabilities.

With no or little genetic correlation with either growth or muscle and IMF, sires can be identified with high PWT and PEMD that also have high IMF. There is a stronger negative correlation between PFAT and IMF, which means selecting for carcase leanness and high IMF is more difficult, but still entirely possible.

For breeders not using genomics, continued selection for higher PWT and PEMD will produce more lean meat yield with little effect on IMF. Rather than choose a low PFAT (which would also increase LMY), breeders should select moderate values to avoid further lowering IMF.

Progress increasing lean meat yield and maintaining IMF will be a little slower than using the IMF ASBV instead of the PFAT ASBV because PFAT is not a direct measure for IMF and higher PFAT is associated with lower lean meat yield.

Take home messages

- Increasing lean meat yield and maintaining IMF are both essential to the profitability and consumer appeal of lamb.
- Current selection to increase lean meat yield by decreasing PFAT reduces IMF.
- Improved selection can be achieved by using the IMF ASBV (from a genomics test) as a direct measure of IMF to replace the use of PFAT.
- Breeders not using the IMF ASBV should apply only moderate selection pressure using PFAT.
- Breeders can continue to use PWT and PEMD to improve lean meat yield with minimal impact on IMF.
Further information

www.sheepgenetics.org.au

Acknowledgements

This Practical Wisdom note is based on the Sheep CRC’s Information Nucleus Flock research and the resulting articles:


Electrical stimulation for improved eating quality

By Kelly Pearce and David Hopkins

Key points

- Electrical stimulation enhances meat quality by improving tenderness and meat colour and is helping Australian processors to consistently deliver quality sheep meat.
- A number of electrical inputs are available to improve meat quality.
- Medium voltage electrical stimulation units at the start and the end of the chain can improve tenderness and meat colour by increasing the rate of pH decline.
- High frequency immobilisation at the start of the chain reduces animal movement and improves occupational health and safety.
- Low or medium voltage electrical stimulation at the start of the chain can increase the amount of collectable blood and also reduces waste.

Introduction

Electrical stimulation enhances meat quality by improving tenderness and meat colour and is helping Australian processors to consistently deliver quality sheepmeat. Electrical stimulation can also improve occupational health and safety, increase blood collection and enable faster carcase throughput.

A variety of electrical inputs are now available for use by Australian processors. Recent work jointly funded by the Australian Sheep Industry Cooperative Research Centre (Sheep CRC) and Meat and Livestock Australia has been undertaken to ensure the units are optimised to abattoir requirements.

Why use Medium Voltage Stimulation?

A new approach to electrical stimulation has been developed based on medium voltage stimulation (MVS). These systems are favoured over the traditional high voltage systems because they:

- use less electricity and are cheaper to run,
- are safer for workers as they comply with Australian Occupational Health and Safety regulations,
- can be located at either the start or the end of the chain depending on the availability of space, and
- can deliver electricity to each carcase individually, dependant on the responsiveness of that carcase.
How does MVS work?

The system is devised of segmented electrodes that ensure that only one carcase contacts the electrodes at any one time. The current remains constant and the voltage is varied (peak 300V) by controlled electronics, which determine the resistance of the carcase and alter the voltage accordingly through a feedback system.

What are the benefits of MVS?

MVS has a number of benefits. These are improved sheepmeat quality, improved occupational health and safety and increased efficiency.

How is sheepmeat quality improved?

Medium voltage systems are an effective way of controlling the rate of pH decline of carcases post-slaughter. The rate of pH and temperature decline of a carcase can significantly affect meat eating quality. If the pH decline is too slow (high pH at low temperatures) cold shortening may occur. This is extremely detrimental to the quality of the meat and will result in tough meat and darker meat colour. Meat and Livestock Australia’s Sheep Meat Eating Quality program identified that for optimal eating quality, meat intended for the domestic market (short-aged) should come from a carcase that has a pH of 6 between 18 and 35°C carcase temperature.

Table 1. The percentage of carcases achieving pH targets of 6 under stimulation when compared to no stimulation.

<table>
<thead>
<tr>
<th>Carcases at pH=6 between 18-35°C</th>
<th>No stimulation</th>
<th>Electrically stimulated - optimal setting for domestic market (2.5ms, 1A, 15 Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH&gt;6 at 18°C</td>
<td>14%</td>
<td>90%</td>
</tr>
</tbody>
</table>

Figure 1. Medium voltage post-dressing system (6-module unit).
The extremely low compliance level for the rate of pH fall without the use of stimulation was widespread across the industry, thus the encouragement for processors to install MVS. Research aimed at optimising the MVS units to achieve a rate of pH decline that increases the number of carcases that reach a pH 6 between 18 and 35°C has been undertaken.

**Improved occupational health and safety**

The use of high-frequency immobilisation (Figure 3) at slaughter reduces animal movement and enables abattoir workers to begin processing the carcases safely within approximately 30 seconds of death. These systems have also been shown to have no detrimental effect on meat quality.

**Increased efficiency**

If low or medium voltage electrical stimulation is used at the start of the chain (Figure 4), the amount of collectable blood can be increased. This reduces abattoir waste and water use and provides additional income for those abattoirs that process blood. The amount of blood release two minutes post-slaughter was 50% greater when a thoracic stick was used in combination with a Halal slaughter, compared to only a

![Figure 2. A snap shot of lamb tenderness across Australia in 1998 (yellow bars) showed a large variation in shear force, a measure of tenderness. Subsequent sampling of lamb meat from stimulated carcases that were aged for five days (blue bars) revealed the value of adopting technology to accelerate the rate of pH decline after death.](image)
Halal slaughter. Additionally, if the carcase was stimulated with low voltage stimulation (10Hz) at the sticking point, there was a 62% increase. This can improve meat quality and consumer acceptance by making meat lighter and redder in colour.

Electrical stimulation also has other efficiency benefits. Abattoirs can run their chillers at lower temperatures reducing evaporation losses without compromising eating quality.

**Take home messages**

- A number of electrical inputs are available to Australian sheepmeat processors to improve meat quality and occupational health and safety.
- Medium voltage electrical stimulation units at the start and the end of the chain can improve tenderness and meat colour by increasing the rate of pH decline.
- High-frequency immobilisation at the start of the chain reduces animal movement and improves OH&S.
- Low or medium voltage electrical stimulation at the start of the chain can increase the amount of collectable blood and also reduces waste.

**Further information**

For further information visit [www.sheepcrc.org.au](http://www.sheepcrc.org.au)

**Acknowledgements**

This research was funded jointly by the Sheep CRC and Meat and Livestock Australia.
Meat colour and shelf life

By Robin Jacob & Honor Calnan

Key points

- Consumers’ decisions to buy meat are strongly influenced by their perception of colour.
- The stability of meat colour is affected by a number of on-farm, processing and retail display practices.
- Changing some of these practices along the supply chain can therefore improve colour stability, and hence shelf-life, with potentially significant cost savings at the retail level.

Introduction

When meat is sliced, it absorbs oxygen from the atmosphere and the cut surface. Within one hour this process is complete and the surface of the meat is usually bright red; at this stage it is known as the “bloom colour”. However as time progresses, the surface of sliced meat will change from red to brown due to oxidation of the pigment oxymyoglobin to metmyoglobin. As meat becomes brown in colour, as shown in Figure 1 below, it is unattractive to consumers.

How does colour influence purchase decisions?

Consumers’ decisions to buy meat are strongly influenced by meat colour. In a recent consumer survey, 41% of customers said they would not eat meat that appeared brown, even when the use by date had not been exceeded. As a consequence retailers often discount meat to prevent the display period extending beyond two days.

Figure 1. A lamb leg chop showing the change in colour with time from red to brown as the pigment in the meat surface changes from oxymyoglobin to metmyoglobin. The time it takes for meat to deteriorate in colour sets the acceptable time limit for retail display of meat. Currently two days is used as the standard shelf-time for meat packed on polystyrene trays with a polyvinyl over-wrap.
How is colour measured?

For research purposes the change in colour during shelf display is measured by a change in light reflectance at specific wavelengths (630 nm and 580 nm). These measurements are used to calculate the oxymyoglobin/metmyoglobin (oxy/met) ratio and this ratio varies between 7 for very red meat to 1 for very brown meat. The longer the meat is displayed on a retail shelf the lower the oxy/met ratio becomes.

Consumers have identified that when the oxy/met ratio drops below 3.5, the meat is unacceptable. Figure 2 below shows how the colour of the meat deteriorates very quickly once this critical level of 3.5 is reached.

What affects meat colour stability?

Colour stability can be influenced by a number of management factors along the meat supply chain from farm, to meat processing and retail display. A supply chain approach achieves the best result for colour stability.

1. Muscle type

The shelf-life of meat is influenced by the intrinsic biochemical nature of different muscle types. This is important because different cuts contain different muscle types. Some cuts, such as the silverside, do not change in colour within a two-day display time. Other cuts such as topside and rump change colour dramatically within two days.
of slicing (oxy/met will change by greater than 25%). In between these extremes are cuts such as loin, which are intermediate in colour stability. Table 1 below shows the muscle type and their relative stability in colour.

Table 1. Colour stability of different muscles and their commercial cuts.

<table>
<thead>
<tr>
<th>Colour stability classification</th>
<th>Muscle</th>
<th>Commercial cut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable</td>
<td>m. semitendinosus</td>
<td>Eye round</td>
</tr>
<tr>
<td></td>
<td>m. biceps femoris</td>
<td>Silverside</td>
</tr>
<tr>
<td>Intermediate</td>
<td>m. quadriceps femoris</td>
<td>Knuckle</td>
</tr>
<tr>
<td></td>
<td>m. longissimus thoracis et lumborum</td>
<td>Loin</td>
</tr>
<tr>
<td></td>
<td>m. triceps brachii</td>
<td>Shoulder</td>
</tr>
<tr>
<td>Unstable</td>
<td>m. semimembranosus</td>
<td>Topside</td>
</tr>
<tr>
<td></td>
<td>m. gluteus medius</td>
<td>Rump</td>
</tr>
<tr>
<td></td>
<td>m. psoas major</td>
<td>Fillet</td>
</tr>
</tbody>
</table>

However under some circumstances, such as ageing for more than 3 weeks before slicing, cuts that are stable may become unstable in colour. Therefore some care is needed in using this broad classification to compare the colour stability of different cuts. In general terms, if a commercial cut is very red, the colour will be less stable and the more responsive the cut will be to management interventions designed to improve colour stability.

2. Lamb production factors

**Vitamin E**

Vitamin E supplementation can increase the brightness of meat bloom colour as well as the stability of the red colour during shelf display. Vitamin E is a powerful antioxidant whose natural concentration in pastures and crop stubbles decreases seasonally during the dry period. The appearance of brown on the meat surface is an oxidative process; therefore vitamin E concentration in the muscle has an influence on meat colour.

Typically, lambs become deficient in vitamin E during the summer and autumn period in southern Australia (or when there is limited green feed in other areas). Meat derived from lambs that are deficient in vitamin E at the time of slaughter will have poor shelf-life based on colour. This seasonal effect can be avoided by increasing the amount of vitamin E added to finishing diets. For lambs that have not grazed green feed for longer than six weeks, a higher than normal feeding rate (than recommended
for animal health and production) is recommended, being 250 ppm 2–4 weeks prior to
slaughter. However a nutritionist should be consulted and the cost considered before
doing this.

**Finishing diet energy and pre-slaughter stress**

The energy content of the diet during the finishing period and the amount of stress
the animals experience prior to slaughter both affect the glycogen content of muscle,
which affects meat colour (and other meat quality attributes). After slaughter,
glycogen is converted to lactic acid and this will influence the pH (pH24) of the meat
post mortem. Meat with low glycogen stores has a high pH causing it to be dark and
less stable in colour. Higher energy diets will increase the stored glycogen in the
muscles; stress and exercise prior to slaughter reduce it. Finishing diets should have
enough energy to ensure a growth rate of at least 100 g/head/day and all efforts
should be made to reduce handling stress prior to and during loading and transport of
animals and in lairage.

**Lamb age**

Over the length of the annual lamb production cycle lamb age increases as production
changes from “suckers” that are 4–6 months of age to “carry-overs” that are 8–12
months of age. As lamb age increases a subtle change in meat colour occurs. Meat
from “carry-over” lambs tends to be darker, more intense, less stable and more
variable in colour than meat from “sucker” lambs. These changes result from muscle
pigment (myoglobin) increasing with lamb age, but may also be due to changes in
feed type as the seasons change.

**Lamb genotype**

Selection for growth rate and muscling has the potential to change the colour of lamb
meat. Lambs selected for muscling may have lighter coloured meat, which is more
acceptable, and this is the subject of further research in the second phase of the
Sheep CRC. Leg cuts from Merino lambs may be darker, less red in colour and less
stable in colour during retail shelf display than those from crossbred lambs of the
same age. However, this difference has not been seen with Merino loins.
3. Meat processing factors

Electrical stimulation

The effect of electrical stimulation depends to some extent on the type of system used, but a general effect of electrical stimulation is to make the bloom colour lighter and more attractive to consumers. New generation medium voltage systems generally have no effect on colour stability whilst high voltage systems may cause a small reduction in colour stability. However, these effects depend to some extent on the muscle type and other production and processing factors.

Primal packaging systems

Packaging meat as primal cuts in carbon dioxide causes meat to be redder in hue and more stable in colour compared to meat kept in carcase form exposed to air. Packaging in carbon dioxide can also reduce the likelihood of electrical stimulation having a negative effect on colour stability.

Ageing period

Ageing meat to improve tenderness can reduce colour stability. This effect is seen for meat aged longer than 10 days and the maximum time suggested for ageing without substantial detrimental effects on colour stability is 20 days. If meat is to be aged for extended periods of time, carbon dioxide gas packaging should be considered and the vitamin E status of the lambs should be known. Cuts that are normally stable in colour, such as the silverside, become very unstable in colour when aged for longer than three weeks prior to slicing for retail display. Figure 3 illustrates the effects of ageing and vitamin E supplementation on shelf-life.
Chilling rate and hot boning

Rapid chilling can improve the colour stability of meat. Hot boning can cause meat to appear darker in colour compared to cold-boned meat.

Freezing

Meat that has been frozen tends to be less stable in colour than fresh meat.

4. Retail factors

Packaging

Modified atmosphere packaging (MAP) can improve colour stability. These systems involve packaging in an oxygen impermeable package that contains a carbon dioxide, nitrogen and oxygen gas mixture. Control of this gas mixture can influence the rate of oxidation of myoglobin. A study in Victoria has shown that MAP doubled the acceptable shelf-life of lamb meat.

Temperature

The rate of oxidation (browning) increases as the temperature of the display cabinet increases. Display cabinets should be kept as low as possible. Temperature fluctuations will also promote oxidation.

Lighting

Light can speed the oxidation process so the more intense cabinet lighting is, the faster the meat will discolour.
Take home messages

Colour stability, and hence shelf-life, can be improved by:

- ensuring vitamin E nutrition of lambs pre-slaughter is adequate
- provide a finishing diet that will achieve growth of at least 100 g/head/day
- reduce stress in the week leading up to slaughter
- use of medium voltage stimulation systems
- packaging in carbon dioxide
- ageing of meat for no longer than 10 days
- ensuring vitamin E nutrition is adequate if ageing is longer than 20 days
- use of rapid chilling
- use of modified atmosphere packaging
- low temperature and low intensity lighting in display cabinets

Meat that is of higher risk of colour instability comes from:

- cuts including the topside, rump and fillet
- older lambs
- Merino lambs

Further information

- www.sheepcrc.org.au

Acknowledgements

This research was funded jointly by the Sheep CRC and Meat and Livestock Australia.
Optimising breeding objectives for current and future markets

Steve Milne, Waratah White Suffolks, Vic

With sheep breeders increasingly adopting targeted breeding tools through Australian Sheep Breeding Values (ASBVs), advanced breeding techniques and DNA testing, the challenge for industry is to optimise their use in breeding programs to ensure an individual’s business objectives are achieved as well as meeting the needs of future markets.

About Steve Milne

Steve is the principal of Waratah White Suffolk Stud, Branxholme, Vic, which was established in October 1995, and he has a Master’s degree in Animal Science (Animal Breeding Management) through Sydney University.

To rapidly improve the genetic composition of the Waratah flock, breeding technologies including embryo transfer and artificial insemination have been extensively used, along with the objective genetic assessment on offer from ASBVs.

“We believe that LAMBPLAN offers the best objective assessment of an animal’s genetic merit,” Mr Milne said. “Measuring all lambs gives us the most accurate and consistent information from LAMBPLAN.”

To assist commercial clients in adopting ASBVs as part of their breeding programs, Mr Milne hosted a RamSelect workshop in 2012.

RamSelect workshops help producers develop skills to accurately and confidently select rams to meet their breeding objectives and improve their sheep enterprise returns.

“Selecting rams is one of the biggest decisions a breeder will make each year as it can have an effect on the flock for many years to come,” he said.

“It’s important that breeders have confidence in using all of the tools available when selecting genetics to meet their breeding objective and their target markets, be it for wool, meat or dual-purpose.”
Take home messages

- Objective measurement tools can help ensure ram selection is aligned to breeding objectives.
- ASBVs are calculated by MERINOSELECT and LAMBPLAN to compare the genetic potential of animals independent of their environment and location.
- The challenge for industry is to develop breeding programs that optimise objective tools and align with market needs.

Further information

The Sheep CRC’s RamSelect program provides a hands-on practical approach to using Australian Sheep Breeding Values (ASBVs) for ram selection so that sheep breeders can maximise genetic gain and increase profit from their wool and meat businesses.

More information on how to optimise breeding programs through the use of ASBVs and genomic breeding values is also available from the Sheep CRC and Sheep Genetics.

- www.sheepcrc.org.au
- www.sheepgenetics.org.au
- www.waratahwhites.com.au
Technical Note

Lamb nutritional value

Consumers demand lamb meat that is lean, palatable and has a good nutritional value. Nutrients such as iron and zinc are important for human health and represent a key marketing tool for red meat.

Current levels and targets

Nutrient levels need to account for 10% or 25% of the recommended daily intake to achieve a source or good source claim from one serving of food. One serve of lamb is considered to be 135 g of fresh meat.

Table 1. Mineral concentration in INF lambs.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Average</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>2.0 mg/100 g</td>
<td>0.8-4.0 mg/100 g</td>
</tr>
<tr>
<td>Zinc</td>
<td>2.4 mg/100 g</td>
<td>1.2-4.5 mg/100 g</td>
</tr>
</tbody>
</table>

Based on the average level of iron and zinc of the Sheep CRC Information Nucleus flock (INF) (Table 1), Australian lamb can predominantly be claimed as a good source of iron and zinc. However, there is still room for improvement, because a good source claim cannot be made for iron in younger women and zinc in all men.

Physical associations with iron and zinc

Data from the INF lambs has shown a range of non-genetic factors that are significantly associated with the iron and zinc content in muscle.

Figure 1. Iron and zinc concentration increases with slaughter age.
Slaughter age

Age is a key driver of iron and to a lesser extent of zinc. The mean slaughter age from the INF lambs measured for iron and zinc is 268 days, with a range of 134–504 days. Across this range, both iron and zinc increase by 0.75 and 0.57 mg/100 g (Figure 1).

Age also impacts on the muscle oxidative capacity, with older animals having been associated with a more oxidative, redder muscle fibre type. This is reflected through higher levels of the protein myoglobin which is the key red pigment of muscle.

Myoglobin

Myoglobin is an indirect indicator of muscle oxidative capacity, with higher levels of muscle myoglobin causing redder meat (Figure 2).

Both iron and zinc increase as myoglobin increases, however, the effect was three times bigger for iron than for zinc given its direct association with haem-iron. The mean myoglobin from the INF lambs tested for the minerals is 6.6 mg/g, with a range of 2–13 mg/g.

Intramuscular fat percentage (IMF%)

Both iron and zinc levels increase with higher IMF% levels. The mean IMF% is 4.2%, with a range of 2–7%. IMF% is also associated with myoglobin, which increases with higher IMF% levels.

This highlights the concerns that selection for lean meat yield, which reduces IMF% and the proportion of oxidative fibres, might subsequently reduce iron and zinc concentrations.

Genetic associations with iron and zinc

Genetic correlations

Both iron and zinc have a low to moderate heritability, as does myoglobin. Consistent with the phenotypic associations, both minerals have a positive genetic correlation with IMF% and myoglobin. Myoglobin also has a positive genetic correlation with colour stability and colour redness.
**Sire**

Meat from terminal-sired lambs had the lowest iron levels compared to maternal- and Merino-sired lambs, reflecting the more intense selection pressure for more muscular and leaner animals, note that these lambs are also older. Terminal-sired lambs have also been shown to have less myoglobin, which in part may be associated with their lower mineral levels.

**Sire breeding values**

Lean meat yield selection using sire Australian Sheep Breeding Values (ASBVs) has some impact on the nutrient content in muscle. Selection for leaner animals reduces the iron content (Figure 3), but does not impact the zinc levels, whereas selection for more muscular animals had no impact on both minerals. This confirms the minimal impact that selecting for lean meat yield would have on these nutrients.

Furthermore it has been shown that selection for lean meat yield reduced oxidative capacity via reduced myoglobin levels.

**Take home messages**

Lamb contains substantial concentrations of iron and zinc, however, there is some room for improvement. Iron and zinc increase with age and IMF%. Care must be taken to avoid lower levels. Selection for lean meat yield reduces IMF% and oxidative muscle fibres, possibly lowering iron and zinc levels.

**Further information**

- Sheep CRC Information Nucleus: www.sheepcrc.org.au
- AMPC Fact Sheet: Intramuscular fat%
Lamb weight and growth rate

Several key production factors influence lamb weights, as found in the Sheep CRC Information Nucleus flocks.

Lamb factors include sex, birth type (single, twin or triplet) and sibling competition during rearing (rear type: single, twin or triplet), as well as the type of sire of the lamb (maternal, terminal or Merino).

The age and breed of the dam can also be influential. The same production factors that influence lamb weight also influence growth rate at key time points. The key findings of Sheep CRC studies into each of these factors are presented below, with the data shown over page (Table 1).

**Sex**

Wether (castrated male) lambs are heavier and faster growing.

- Wether lambs were 5–8 % heavier than female lambs between birth and 240 days.
- Wether lambs were also faster growing than female lambs between birth and 240 days.
- The difference in growth rate between wether and female lambs increased over time, with male lambs growing faster by 1% at 100 days and 33% at 240 days.

**Birth type and rear type**

Single born lambs are heavier and grow faster initially, however triplets grow the fastest after weaning due to compensatory growth.

- Single born lambs were on average 22% heavier than twins at birth and 44% heavier than triplets.
- These weight differences reduced to 9% and 17% respectively at 240 days because twins and triplets gained proportionately more weight than singles.
- Within a birth type, lamb weight was increased with the loss of a sibling, as there was less competition for nutrition. For example, twin born lambs that are raised as single lambs are consistently heavier than lambs born and raised as twins.
• Lambs raised as singles initially grew the fastest. Post weaning, lambs born as multiples experienced a period of compensatory growth, resulting in them growing faster than single born lambs, although they did not catch up completely.

**Sire type**

Progeny of terminal sires are heavier and faster growing.

• Progeny of terminal sires were 11% heavier than progeny of Merino sires and 8% heavier than progeny of maternal sires at birth.
• These weight differences increased to 42% and 16% respectively at 240 days.
• Progeny of terminal sires grew up to 150% faster than progeny of Merino sires, which caused these large differences in weight.

**Dam age**

Lambs born to 2-year old dams are lighter.

• At birth, lambs born to 2-year old dams were as much as 10% lighter than lambs born to older dams. This 10% difference in weight was also present at 240 days.
• At weaning, lambs born to 2-year old dams were the slowest growing, by up to 160%.
• Post weaning, lambs born to 2-year old dams experienced compensatory growth, although they did not achieve the same weights as lambs born to older ewes.

**Dam breed**

Terminal-sired lambs with Merino dams are lighter.

• Of lambs born to terminal sires, lambs with a Merino dam were between 10 and 16% lighter than those born to Border Leicester-Merino dams and grew up to 8% slower.
Table 1. Lamb weights at birth, 100, 150 and 240 days for different sexes, birth type-rear types, dam ages, sire types and dam breed within sire type combinations. (For birth type-rear type levels, birth type is listed first followed by rear type. For example, with level 32, the 3 indicates lambs born as triplets and the 2 indicates they were reared as twins.)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>Birth weight (kg)</th>
<th>Wt day 100 (kg)</th>
<th>Wt day 150 (kg)</th>
<th>Wt day 240 (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>F</td>
<td>4.56</td>
<td>26.63</td>
<td>32.52</td>
<td>40.61</td>
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<tr>
<td></td>
<td>M</td>
<td>4.87</td>
<td>28.22</td>
<td>34.25</td>
<td>43.81</td>
</tr>
<tr>
<td>Birth type-rear type</td>
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<td>5.62</td>
<td>31.89</td>
<td>37.50</td>
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<td></td>
<td>21</td>
<td>4.61</td>
<td>29.27</td>
<td>35.16</td>
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<tr>
<td></td>
<td>22</td>
<td>-</td>
<td>26.75</td>
<td>32.61</td>
<td>41.80</td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>3.91</td>
<td>28.45</td>
<td>34.44</td>
<td>42.66</td>
</tr>
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<td></td>
<td>32</td>
<td>-</td>
<td>25.09</td>
<td>31.20</td>
<td>40.81</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>-</td>
<td>23.12</td>
<td>29.41</td>
<td>38.86</td>
</tr>
<tr>
<td>Dam age</td>
<td>2</td>
<td>4.41</td>
<td>27.57</td>
<td>31.82</td>
<td>39.00</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4.58</td>
<td>27.53</td>
<td>33.47</td>
<td>42.42</td>
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<td></td>
<td>5</td>
<td>4.78</td>
<td>28.10</td>
<td>33.90</td>
<td>42.66</td>
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<td>6</td>
<td>4.81</td>
<td>28.76</td>
<td>33.82</td>
<td>42.45</td>
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<tr>
<td></td>
<td>7</td>
<td>4.79</td>
<td>26.91</td>
<td>33.52</td>
<td>42.72</td>
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<tr>
<td></td>
<td>8</td>
<td>4.86</td>
<td>25.28</td>
<td>33.05</td>
<td>43.25</td>
</tr>
<tr>
<td>Sire type - Dam breed</td>
<td>Maternal-Merino</td>
<td>4.62</td>
<td>27.13</td>
<td>33.62</td>
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<td></td>
<td>Merino-Merino</td>
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<td>23.43</td>
<td>28.49</td>
<td>34.74</td>
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<td>Terminal-Merino</td>
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<td>29.40</td>
<td>35.63</td>
<td>47.08</td>
</tr>
<tr>
<td></td>
<td>Terminal-Cross Breed</td>
<td>5.23</td>
<td>34.04</td>
<td>40.48</td>
<td>51.78</td>
</tr>
</tbody>
</table>

Summary

The most rapid growth and earliest turn off can be achieved by the combination of these factors:

- single lamb
- male lamb
- dam over two years old
- terminal sire
- terminal x Merino dam
Lamb eating quality

Key points

- Lamb eating quality is affected by a range of on-farm and genetic factors.
- The MSA lamb grading model can be improved by incorporating factors, in particular, intramuscular fat, muscling and sire information.

Introduction

Consumers demand premium quality and value for money when purchasing lamb. They are willing to pay more for a higher quality product, especially when the quality can be guaranteed. Previous research has shown that if the price of ‘good every day’ Meat Standards Australia (MSA) quality lamb (3 star) is set to 100%*, then consumers are prepared to pay differing prices for other grades of product (Table 1).

What factors affect lamb sensory scores?

The Sheep CRC Information Nucleus flock (INF) has provided an opportunity to understand the range of genetic and non-genetic factors that significantly affect consumer sensory scores for eating quality. Untrained consumers were recruited to test grilled samples of the longissimus lumborum (loin) and semimembranosus (topside) muscle from 1,471 lambs for tenderness, juiciness, flavour, odour and overall liking score using a 1–100 scoring system.

Effect of carcase fat on lamb eating quality

Shortloin fat weight, calculated as the fat from a denuded short loin, is a good indicator of total carcase fatness. Adjusted to the same hot carcase weight, the sensory scores of both loin and topside cuts showed a small increase as shortloin fat weight increased.

The mean shortloin fat weight from the INF lambs tested for eating quality was 249 g (range 40–880 g). Up to a 450 g short loin fat weight, sensory scores increased by 3 (tenderness) and 2 (overall liking) consumer scores, however, after this there is no further improvement.

Table 1. Consumer willingness to pay.

<table>
<thead>
<tr>
<th>Quality</th>
<th>MSA Grade</th>
<th>Willingness to pay*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premium</td>
<td>5 star</td>
<td>200%</td>
</tr>
<tr>
<td>Better than every day</td>
<td>4 star</td>
<td>147%</td>
</tr>
<tr>
<td>Good every day</td>
<td>3 star</td>
<td>100%</td>
</tr>
<tr>
<td>Ungraded</td>
<td>2 star</td>
<td>49%</td>
</tr>
</tbody>
</table>
Effect of muscle on lamb eating quality

Shortloin and topside muscle weights are good indicators of whole carcase muscle weight. Muscling measured by shortloin and topside muscle weight has a negative relationship with consumer sensory scores.

The mean shortloin muscle weight measurement from the INF lambs tested for eating quality was 367 g (range 170–635 g) and the mean topside muscle weight was 617 g (range 350–1010 g). Adjusted to the same hot carcase weight, increased muscling decreases the sensory scores. This effect ranged from 3–7 consumer scores for the loin (between 200–560 g) and 4–9 for the topside (between 400–880 g), with the highest impact on tenderness, followed by overall liking, juiciness and flavour.

Effect of production and management factors on lamb eating quality

Factors such as location (research station), year of birth, gender, dam breed and age at slaughter have a small (significant) impact on the consumer sensory scores. This indicates that the MSA system is an effective grading system to deliver good eating quality and minimizes the impact these production effects have on eating quality.

Grilled loin samples (mean overall liking score = 72) were more acceptable for consumers than grilled topside samples (mean overall liking score = 52), indicating that integration of the different cuts is a vital factor in optimising sheep meat eating quality.

Effect of intramuscular fat (IMF%) on lamb eating quality

Intramuscular fat contributes to the juiciness, flavour and tenderness of cooked meat. Animals with higher IMF% levels will produce meat that is more acceptable for consumers. The measured IMF% range in Information Nucleus Flock lambs was 2–7%, with a mean value of 4.2%. The preferred range in lamb is between 4 and 6%.

IMF% is a strong driver of consumer sensory scores, increasing all sensory traits (Figure 1). The highest impact was on juiciness resulting in an increase of 11 consumer scores across the IMF% range. The increase for overall liking was 10 consumer scores, 9 scores for flavour and 6 scores for tenderness.
Effect of sires on lamb eating quality

Sire had a significant effect on sensory score with a range of 4 consumer scores for flavour to 10 consumer scores for tenderness for both the loin and topside samples (Figure 2). These differences are sufficient to change the final consumer rating of the steaks and shows that genetic effects need to be considered in the development of an updated MSA lamb grading model.

Figure 1. IMF% impact of the loin on consumer sensory scores.

Figure 2. Sire variation on consumer tenderness scores for loin and topside. Each point represents the mean of all progeny from a sire.
Meat from terminal-sired lambs had the lowest sensory scores compared to maternal- and Merino-sired lambs, reflecting the more intense selection pressure for more muscle and therefore higher lean meat yield. Terminal-sired lambs have been shown to have less IMF%, which in part may be associated with the lower sensory scores.

Selection for more muscular and leaner animals using sire Australian Sheep Breeding Values has been shown to reduce the consumer sensory scores. This confirms the growing concerns that selecting for higher lean meat yield would reduce consumer eating quality and highlights the need for careful monitoring of selection programs to maintain high lamb eating quality.

**Take home messages**
- Sensory scores increase with higher IMF%, higher fatness and lower muscling. These associations, together with the sire information, should be incorporated in the development of an enhanced MSA lamb grading model to better predict the lamb eating quality.

**Further information**
- Sheep CRC Information Nucleus: www.sheepcrc.org.au
- AMPC Fact Sheet: Intramuscular fat%
Technical Note

New breeding values for yield and eating quality

Key points

- New carcase and meat eating quality breeding values allow producers to directly select traits of importance.

Introduction

Genetics play a significant role in productivity and profitability. Recent research has shown many carcase traits are moderately to highly heritable and provide good opportunities to improve lamb.

Australian Sheep Breeding Values (ASBVs) are an estimate of an animal’s true breeding value based on pedigree, genomic and performance-recorded information for a range of traits.

What are the new meat traits?

The following new traits have been identified by the Sheep CRC and the Sheep Genetics Technical committee as potentially impacting on either carcase dimensions, yield or the eating quality of Australian lamb:

- Hot Carcase Weight (HCWT; kg)
- Carcase Eye Muscle Depth (CEMD; mm)
- Carcase Fat (CFAT; mm)
- Lean Meat Yield (LMY; %)
- Intramuscular Fat (IMF; %)
- Shear Force (Tenderness) (SHEARF5; kg)

These breeding values are being released to industry, although none of these traits are currently included in any of the standard LAMBPLAN or MERINOSELECT indexes (as of January 2014).

Data from the Sheep CRC Information Nucleus flock (INF) has enabled these traits to be developed. Traits have been measured over five years, across a range of environments, on 4,500 ewes, 500 rams and greater than 10,000 progeny, to gather this information.
**Carcase Weight (HCWT; kg)**

*Hot carcase weight of the animal, measured in kilograms.*

HCWT is a function of live weight and the dressing percentage.

The Research Breeding Value (RBV) ranges around 0, with higher values indicating genetic makeup for increased carcase weight.

**Carcase Eye Muscle Depth (CEMD; mm)**

*Eye muscle depth of the loin taken from a quartered carcase, measured in millimetres.*

It is adjusted to a constant weight—in this case carcase weight—in the same way that the ultrasonic measure of post-weaning eye muscle depth breeding value (PEMD) is adjusted to constant live weight.

CEMD has been shown to influence lean meat yield and the weight particularly of the loin muscle. It is correlated with the PEMD taken on a live animal.

The mean CEMD measurement from the INF is currently 30 mm, with a range of 17–45 mm. The RBVs range around 0, with higher values indicating genetic makeup for increased carcase muscling.

**Carcase Fat (CFAT; mm)**

*Depth of fat taken at the C site in a quartered carcase, measured in millimetres.*

It is adjusted to a constant weight—in this case carcase weight. This is the same way that the PFAT breeding value is adjusted to constant live weight.

This trait has been shown to influence lean meat yield and strongly reduce the GR tissue depth. The trait is correlated with the ultrasonic measure of post weaning fat (PFAT) in the live animal, though it is not as strong as the relationship between muscle traits.

The mean CFAT measurement from the INF is currently 4 mm, with a range of 0.2–24 mm. The RBVs range around 0, with lower values indicating genetic makeup for reduced carcase fat cover.
Lean Meat Yield (LMY; %)

*Commercial yield of lean meat as a percentage of hot carcase weight.*

Lean meat yield is estimated from a combination of weight, muscle and fat dimensions and has been validated by either CT-scanning or through direct commercial bone-outs.

LMY has a moderate heritability, with the normal range in lamb between 51 and 58%. The RBVs range from +1.9 to -2.0%, with higher values indicating genetic makeup for higher LMY.

Intramuscular Fat (IMF; %)

*Chemical fat percentage in the loin muscle of a lamb, often referred to as marbling.*

The preferred range in lamb is between 4 and 6%, with a current industry mean value of 4.3%. IMF has been shown to have a significant positive impact on the MSA sensory attributes of lamb (flavour, juiciness, tenderness and overall likeability).

IMF has a moderate to high heritability and high negative correlation with shear force. That is, high IMF increases tenderness.

The measured range in IMF lambs is 2–10%. The RBVs range from 0.7 to -0.5%, with higher values indicating genetic makeup for higher IMF%.

Shear Force (Tenderness) (SHEARF5; kg)

The force (or energy) required to cut through the loin muscle of lamb after 5 days of ageing, reported in kilograms of force.

The trait has moderate–high heritability and a moderate correlation with tenderness in lamb. The preferred value for lamb is 3kg or less.

The mean SF5 from the IMF lambs is currently 2.4 kg with a range from 1.1–7.7 kg. The breeding values for this trait range between -3.9 and +4.9 with more negative values indicating genetic makeup for lower shear force, or more tender meat.

How can eating quality breeding values be used?

ASBVs allow for selection of traits that can not be visually selected in a live animal. They can be used in a breeding program to improve the performance of future generations, or to purchase stock that are likely to be more productive and have better eating quality, lean meat yield and colour.
Lean Meat Yield and Dressing Percent

Lean meat yield determines the financial value of a carcase. Preliminary figures suggest an $80 difference along the supply chain between a 23 kg, score 2 carcase versus a 23 kg, score 4 carcase.

Genetics play a significant role in LMY%, with progeny of sires with low genetic fatness (scanned trait = PF) and high genetic muscle (scanned trait = PEMD) ASBVs having a decreased whole carcase fatness and increased muscularity. Carcase weight (the other dimension of LMY) is highly heritable and directly related to weaning and post-weaning weight ASBVs.

Dressing percent (%) is the proportion of carcase weight to liveweight. Dressing% is higher in progeny of sires with higher muscling ASBV (scanned trait = PEMD), producing a lamb of similar live weight, but delivering a markedly larger carcase at slaughter.

Eating quality

Shear force of the loin is under significant genetic control and contributes to tenderness, as do processing conditions and meat pH.

Intramuscular fat (IMF) ensures adequate flavour and juiciness for consumers and is also genetically correlated with shear force. Higher IMF produces more tender meat.

Both of these traits will play a role in the new cuts-based MSA system for lamb.

Take home messages

- Genetics play a significant role in productivity and profitability. ASBVs or RBVs allow for selection of difficult to measure traits to improve breeding programs.
- The new traits identified have a significant impact on carcase dimensions, yield and eating quality of lamb.

Further information

- LAMBPLAN and MERINOSELECT: http://www.sheepgenetics.org.au