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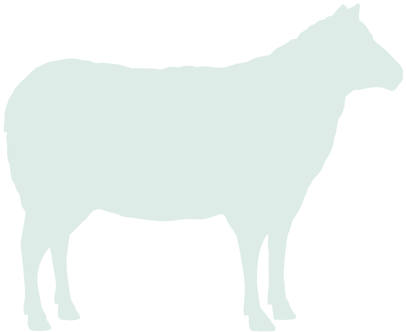

# IMPROVING LAMB LEAN MEAT YIELD

## A TECHNICAL GUIDE FOR THE AUSTRALIAN LAMB AND SHEEP MEAT INDUSTRY

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mla
MEAT & LIVESTOCK AUSTRALIA

# Contents

# How to use this guide

This technical guide has been written as a reference for the lamb meat industry to explain lean meat yield (LMY%) and the factors that influence it. LMY% is an important profit driver for the lamb meat supply chain, however, increasing LMY% can reduce meat eating quality. The link between LMY% and eating quality needs to be kept in mind at all times, with key points about the relationship between LMY% and eating quality covered in each chapter. More information on lamb eating quality can be found in the Sheep Meat Eating Quality (SMEQ) Manual.

A chapter is devoted to each sector of the industry: lamb production, path to slaughter, lamb slaughter and retailing (carcase processing). Each chapter has a value proposition, key principles, research findings and practical steps that apply to that sector. The research findings support the key principles with actual data gained mainly from the Sheep CRC Information Nucleus Flock (INF).

All industry participants are encouraged to read all chapters to gain an understanding of the issues faced across the supply chain and to make the most of the information in this guide.

Some topics are detailed more in some sectors than others. For example, topics such as sheep genetics and growth patterns are featured in the sheep production section. Measurement of yield typically occurs at the time of slaughter, so measurement technologies have been detailed in the lamb slaughter chapter.

Lean meat yield is an important piece of information that can be used by both the supply (production, logistics), and the value (provenance, product development, branding) components of producing sheep meat. Passing the information efficiently across sectors will have benefits for the whole chain.

**Table 1.** Chapter overview and description of detail.

| Chapter | Aimed at | Description |
|---|---|---|
| **1. Lamb production** | Producers and livestock buyers | Identify the effect of management on animal performance and LMY% |
| **2. Path to slaughter** | Producers, transporters, livestock buyers and processors | Understand the effects of the transport saleyard and lairage periods on LMY% |
| **3. Slaughter** | Abattoirs | Identify the LMY% measurement and feedback options for meat processors |
| **4. Retail** | Domestic retail, butchers and supermarkets, exporters, importers and processors | Identify the value of LMY% for optimising fabrication and the needs of consumers |

# Introduction

## Components of a carcase

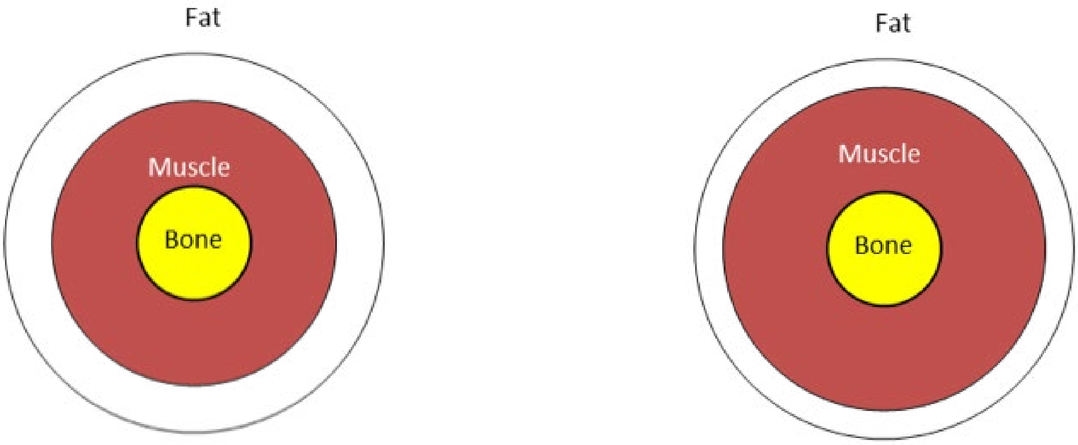
Whilst its physical dimensions may vary, a carcase will always contain just three types of tissue: bone, fat and meat (Figure 1).

**Figure 1.** The three components of a carcase: bone (centre), fat (left) and meat (right).

The relative amount of these tissue types varies between individual carcases (Figure 2). Bone is generally the smallest and meat the largest component of a carcase.

In combination with carcase weight, LMY% can be used to determine the amount of meat available for sale from a carcase. This, along with other factors such as eating quality and provenance, will determine the value in dollar terms of a carcase in a marketplace.

**Figure 2.** A schematic representation of the relative amounts of bone, fat, and meat in carcases with low and high LMY%. The area of each circle equals the percentage of each component of a whole carcase.



**Low yielding carcase**
Bone 9%
Fat 51%
Meat 40%

**High yielding carcase**
Bone 9%
Fat 28%
Meat 63%

## Definitions

### Lean meat yield (LMY%)

Lean meat yield (LMY) is the weight of lean meat tissue (excluding bone and fat) in a carcase, divided by the total weight of the carcase. It is generally expressed as a percentage (LMY%).

LMY% calculation example:

Weight of carcase (HSCW) = 23kg

Weight of lean meat = 10kg

LMY%= 10/23*100 = 43%

LMY% allows for standardised comparisons to be made and does not vary with cutting specifications like saleable meat yield (SMY%). By providing a better description of the intrinsic attributes of a carcase than SMY%, LMY% is suited to applications such as research, fabrication decisions and for the standardised feedback of information to producers.

### Dressing percentage (DP%)

DP% is an important consideration for producers when marketing lambs but has no direct influence on and should not be confused with lean meat yield. The purpose of mentioning it here is simply to demonstrate the difference between dressing percentage and lean meat yield.

DP% is the weight of a carcase, expressed as a percentage of the live weight of the animal from which it was processed. The practical use of dressing percentage for marketing lambs is fully described in the Sheep Assessment Manual published by the MLA Market Information Services.

DP% calculation example:

Live weight of lamb = 50kg

Weight of carcase (hot standard carcase weight) = 23kg

DP% = 23/50*100 = 46%

Producers can use DP% to estimate carcase weight from live weight to meet market specifications.

### Saleable meat yield (SMY%)

SMY% is the weight of saleable product, as sold to consumers in the form of retail cuts, divided by the total weight of the carcase, expressed as a percentage.

SMY% calculation example:

Weight of carcase = 23kg

Weight of retail cuts = 20kg

SMY%= 20/23*100 = 87%

Many retail cuts include some bone and fat as well as meat, depending on the cut. A lamb cutlet is a good example of this (Figure 3).

**Figure 3**. **Lamb cutlets contain all three carcase tissues: about 20% bone, 40% fat and 40% meat as shown.**

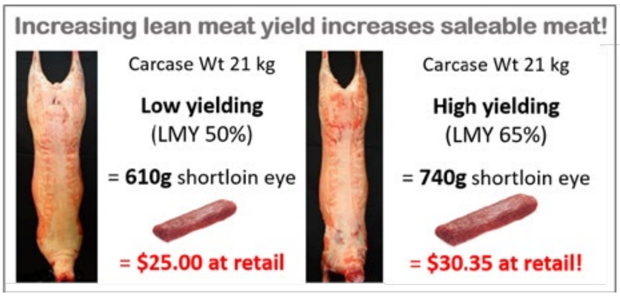
SMY% is therefore dependent upon the specifications used to fabricate the retail cuts, particularly the level of fat trimming used. Cutting specifications vary between individual product lines for different processing enterprises. For example, a leg may be sold as a whole leg or broken down further into smaller cuts such as chump, easy carve leg, knuckle and round cuts. The weight of the retail cuts left after trimming will depend on which of these specifications is used, hence the SMY% will vary accordingly. Typically, the heavier and fatter the carcase the more fabrication into de-boned and highly trimmed cuts.

### LMY% is related to SMY%

Increasing the proportion of lean muscle in a carcase (LMY%) will increase the saleable meat in a carcase (SMY%). The increased quantity of saleable meat combined with the savings made by trimming less fat is the basis of the value of LMY%.

The example shown below (Figure 4) demonstrates the different value in a single cut between low and high-yielding carcases of the same weight.

**Figure 4.** **An example of how lean meat yield can increase saleable meat for a low and a high yielding carcase of the same weight for a specified cutting plan.**



The greater the level of fabrication the lower the SMY%, as trim is removed and cuts are reduced to smaller (more expensive) meal-based portions (e.g. to produce a deboned leg or shoulder roast). However, the relationship between LMY% and SMY% is similar regardless of the level of fabrication. This can be seen in Figure 5, where for both a standard and a value-added fabrication method, SMY% is shown to increase as LMY% increases. LMY% is therefore a commercially valid way of comparing carcases for yield regardless of the level of fabrication.

**Figure 5.** Saleable meat yield depends on the level of fabrication, but generally increases as lean meat yield increases. A six-way cut format was used for the standard fabrication (data sourced from Hocking Edwards, 2018).

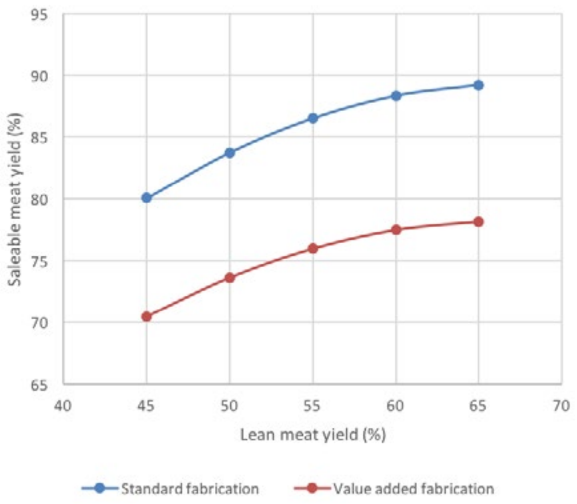


**Table 2.** Specifications for standard and value add fabrication methods used in Figure 5.

| Standard | Value added |
|---|---|
| Bone in leg, aitch bone removed | Boneless leg, chump on, shank off |
| Breast | Boneless shoulder |
| Flap | Breast |
| Fore shank tipped | Eye of short loin |
| Neck | Eye of shoulder |
| Short loin trimmed (25mm tail, 6mm fat) | Flap |
|  | Fore shank tipped |
| Square cut shoulder (6mm fat) | Hind shank, bone in |
|  | Neck |
| Trimmed rack (6mm) | Tenderloin butt off |
|  | Trimmed rack (6mm) |

## Chemical lean percent (CL%)

CL% is defined as the amount of lean meat tissue compared to the amount of fat in a sample of homogenised meat product (mince). In practice, it is the lean:fat ratio of trim or sections of primals – the later might be mutton FQ trimmed to 85% CL. In a commercial application, this measure is used to check manufactured products as part of quality assurance protocols using an approved method of sampling and testing. In a research application, this is also used to calibrate instruments used for objective carcase measurement.

As such, there is never any relationship between CL% and carcase yield (neither SMY% nor LMY%), because fat and or lean meat tissues can be added to the mixture separately to adjust the levels to a required amount. The CL% is included in the trade description of a box of meat trim. For example, for 75CL, 75% of the contents of the box will be lean meat tissue as a minimum and the rest (25%) will be fat tissue. Tolerances can be applied where the mean value and variation (confidence limits) have been determined statistically to assure the buyer about the quality of the product. Near infrared spectroscopy (NIR) is commonly used to measure CL in the mixed product for commercial applications, whereas other methods can be used for research applications.

## Eating quality

Eating quality and lean meat yield are linked biologically as well as in a value sense, and this needs to always be kept in mind. In this guide, the eating quality of meat is defined using the Meat Standards Australia (MSA) system. This is based on consumer taste panel work where meat cooked in a standard way is eaten and rated by panels of untrained consumers for key attributes of tenderness, liking of flavour, juiciness and overall liking. The eating quality can be described using the MSA categories shown in Table 3. Consumer scores of eating quality are strongly influenced by the fat contained within the meat (intramuscular fat or IMF%) and by the tenderness of the meat, measured objectively as shear force (SF5).

**Table 3.** MSA eating quality description.

| MSA category | Star rating |
|---|---|
| **Unsatisfactory** | 2 |
| **Good everyday** | 3 |
| **Better than everyday** | 4 |
| **Premium** | 5 |

## Australian research programs

### Sheep CRC

The Sheep CRC was established for a term of seven years from July 2007. The role of this CRC was to facilitate transformation of the sheep industry through making sheep easier to manage, developing the production and processing of meat and wool to meet increasing consumer expectations, and by increasing the uptake of new technologies by the industry. The cornerstone project of the Sheep CRC was the Information Nucleus Flock (INF). The INF was made up of eight sites in key sheep production environments around Australia, where each year 5,000 ewes were artificially inseminated with semen from 100 industry proven sires. The INF developed more accurate breeding values for production traits and identified DNA markers correlated to production traits. The Sheep CRC exceeded the objectives set by the Commonwealth in 2007 for its seven-year research program ending 30 June 2014 and was extended until 2019. The INF has been transformed into the MLA Genetic Resource Flock and is now funded by MLA.

### ALMtech

Advanced livestock measurement technologies (ALMtech) is a rural research & development for-profit project, funded by the Department of Agriculture and Water Resources from 2015 to 2020. This project accelerates the development of technologies to measure traits in live animals and carcases, particularly measures of LMY% and eating quality. More precise and accurate measurement of these key traits will create better feedback to inform genetic breeding databases and to provide better feedback to producers, so they can improve decisions on breeding and animal husbandry.

Improved measurement of live animals and carcases will also be fed forward along the supply chain to allow processors to make better decisions about how to bone out different carcases for different retail markets. To facilitate this flow of information along the supply chain, the ALMTech project will deliver enhanced feedback systems to ensure new information provided by advanced measurement technologies improves the competitiveness and profitability of the red meat value chain. The project capitalises on the co-operation of industry stakeholders to maximise effective decision-making, reduce risk and optimise profits.

### MLA Resource Flock

The MLA Genetic Resource Flock is similar but smaller than the Sheep CRC INF. Consisting of two flocks (one in Katanning WA and the other in Armidale NSW), the MLA Genetic Resource Flock is used to continue progeny testing of industry sires. The purpose being to update breeding values for eating quality and LMY%, extend the Meat Standards Australia (MSA) cuts-based model and to assist with calibration of new measurement devices for both eating quality and LMY%.

## Whole of supply chain strategy

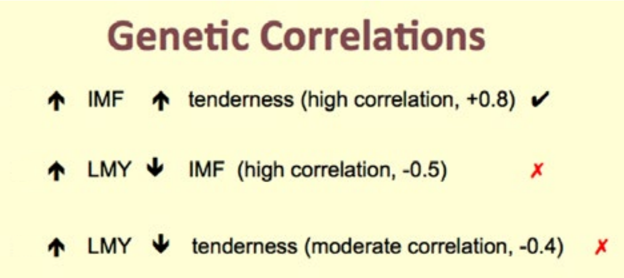
Whilst LMY% is largely determined on farm, a whole of supply chain strategy is essential for the best outcome for all concerned.

### The need for balance between LMY% and eating quality

Without a balanced approach, LMY% and eating quality can work against each other. This is because a number of the eating quality attributes are negatively correlated with LMY% in a genetic sense. Therefore, selecting for high LMY% alone will result in a high yielding animal that has low eating quality. Sheep CRC research has shown consumers value eating quality and are prepared to pay twice as much for a 5-star compared to a 2-star eating quality. However, if the attributes are combined in the selection criteria, progress can be made simultaneously to improve both eating quality and LMY% together.

Such a balanced approach is needed across the length of the supply chain and not just on the farm. If processing grids favour only LMY%, this could encourage farmers to take the emphasis off eating quality to achieve high LMY%. This would be to the detriment of consumers and the industry, because eating quality would decline.

**Figure 6.** The genetic correlations between lean meat yield (LMY) and eating quality traits of IMF and tenderness.



Genetic Correlations

↑ IMF ↑ tenderness (high correlation, +0.8) ✔

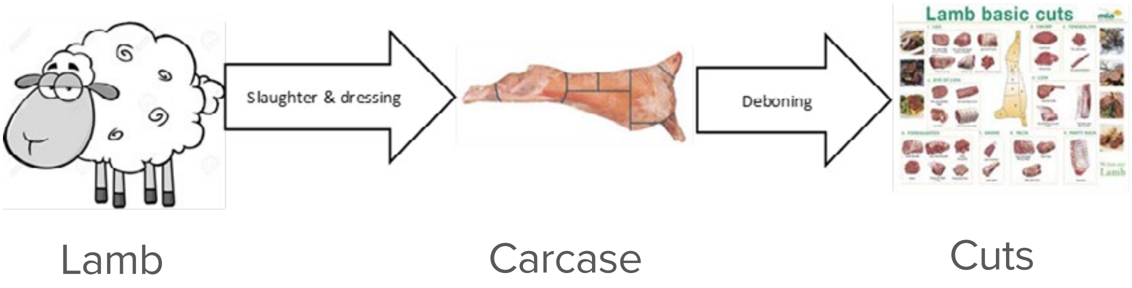
↑ LMY ↓ IMF (high correlation, -0.5) ✗

↑ LMY ↓ tenderness (moderate correlation, -0.4) ✗

### Think supply chain

LMY% is an important descriptor of a lamb carcase that can be used throughout the supply chain. Communicating this information (which is typically collected at the time of slaughter), can be critically important to others in the supply chain.

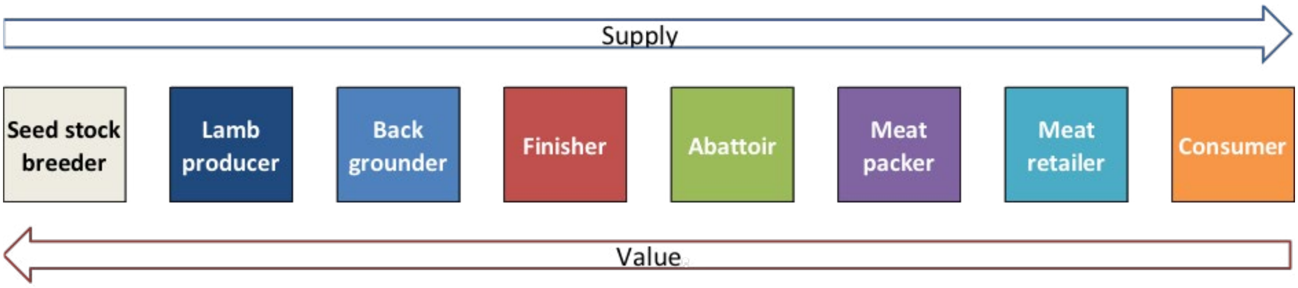
**Figure 7.** The basic steps in meat processing: a lamb is reduced to a carcase, then to primal cuts, then to retail cuts which finally become meals valued by a consumer.



Starting as a lamb, product goes through several steps along a supply chain to eventually become a meal for a consumer. At the industry level, the communication process is a complicated but extremely important task with many participants (Figure 8). Money ultimately starts with the consumer and goes along a value chain, back to the lamb producer.

To make the system work effectively, communication up and down the chain is critically important.  Modern technology will increasingly assist with this communication process to improve information about both supply and value. This includes automated technologies to measure factors such as LMY% and eating quality, but also information systems such as Livestock Data Link to communicate the information gathered. Information about these systems can be obtained in other Meat & Livestock Australia publications.

**Figure 8.** **A simplified representation of the supply and value chains for the lamb meat industry.**



# Chapter 1. Lamb production

## The value proposition for lamb producers – know your lambs

LMY% enables lamb producers to know the value of the lambs they produce and whether improvement is needed through better management. High LMY% can provide a direct benefit to producers by improving the compliance rate with carcase grid specifications when sold directly to slaughter. There are also indirect benefits likely through improved feed conversion efficiency achieved on farm with better yielding animals. However, there are problems with increasing LMY% too far – an accompanying reduction in intramuscular fat (IMF%), tenderness (increased shear force) and therefore eating quality. As a result, selection for LMY% needs to be balanced with selection for eating quality traits.

### Compliance with carcase grids

The price grids for lambs are generally based on carcase weight and fat score. Although the schedules used vary between processors, they are generally designed to reward producers for lambs that cost the least to process and yield meat desired by markets. The latter includes eating quality as well as meat yield and this is described in more detail in the Retail section. Higher yielding animals will generally require less fat to be trimmed, so are cheaper to process and will have more meat that is valued by customers. The higher a producer's compliance rate with price grids, the higher the total price paid for a consignment of lambs.

### Feed conversion efficiency

Feed conversion efficiency (FCE) is a measure of the feed needed to produce live weight gain. This has an influence on the cost and in turn the profit involved in producing a lamb.

FCE = Live weight gain (kg) / Weight of feed eaten (kg)

The higher the FCE the lower the feed cost per kg of live weight gain. Fast growing and high yielding lambs tend to have high FCE, as less energy is required to produce muscle than fat tissue.

As an example, using GR tissue depth as a guide to carcase yield, a 5mm reduction in GR tissue depth (e.g. fat score 3 compared to 4) saves about 1kg of feed dry matter for every 1kg of live weight gain (e.g. 7kg versus 8kg of feed per kilogram of live weight gain). Potentially better feed conversion efficiency can allow higher stocking rates and more profit. In the case of feedlot animals, the amount of grain required will simply be less with more efficient lambs.

## Key principles

### Maturity at the time of slaughter

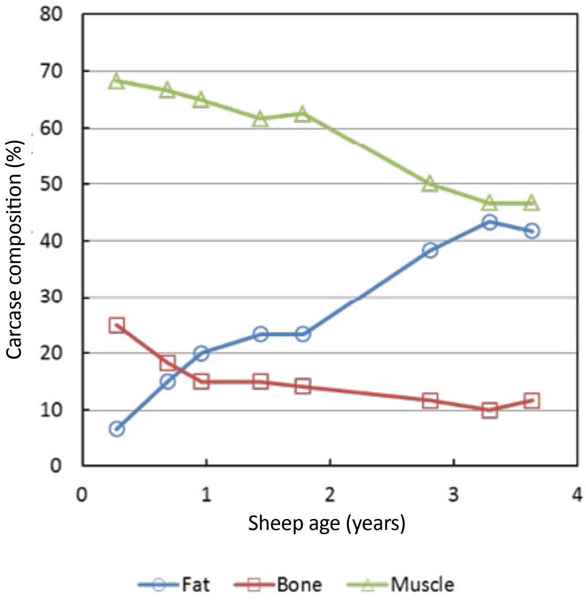
Fast growing lambs that reach slaughter weight at an early stage of maturity will have less fat and more muscle, hence a higher yielding carcase than those slaughtered at a later stage of maturity.

Lambs are generally slaughtered at a target weight to comply with grid and market specifications. Both the age and maturity of lambs can vary at the time of slaughter depending on a lamb's growth path, which will be determined by both genetic and production factors.

Maturity occurs when bone and muscle tissues cease to grow. At this point the lamb has reached 'mature size', although fat tissue can continue to grow if feed intake exceeds maintenance requirements. Both the age and size of a lamb at maturity depend on genotype as well as nutrition.

The relative proportions of bone, fat and muscle tissues change up to the point of maturity (Figure 9). Bone tissue develops early in life and then decreases as a proportion of carcase weight as the lamb grows. Fat tissue is the least developed at birth and increases slowly at first, but the rate increases as the lamb gets older. Therefore, fat becomes a larger portion of the carcase weight as the animal proceeds to maturity. Muscle tissue develops at a similar rate to that of the whole carcase, but as the animal approaches maturity, the muscle weight decreases as a proportion of the carcase weight due to the increase in fat tissue later in life.

**Figure 9.** The proportion of a lamb carcase that is bone, fat and muscle at different ages.



(Adapted from Butterfield et al. (1988))

### Body regions

Individual muscles and bones grow at different rates in the body. For example, the muscle around spinal vertebrae is relatively early maturing, so young animals will have proportionately more lean tissue within the saddle/loin region of the carcase than older animals. As animals approach maturity the spinal muscles will comprise a relatively smaller proportion of total muscle weight.

The major limb bones make up a progressively smaller component of the total bone weight as animals mature. In contrast, lumbar vertebrae increase as a proportion of total bone weight. This is different to that of the surrounding muscles, which decrease as a proportion of the total muscle weight during this time.

In contrast, the regional distribution of fat tissue within the carcase does not significantly change with animal age. Notwithstanding this, the fat within a muscle (IMF%) that strongly influences eating quality, increases with age because fat is deposited at a greater rate than muscle later in life.

LMY% does differ between primal regions of a carcase and this is described in Chapter 4 (Retail).

### Gender

Carcases from females tend to have slightly more fat and lower LMY% than carcases from male animals. Rams are about 1.4 times larger and have proportionately more muscle and bone but less fat than females at maturity (Table 4).

**Table 4.** The body composition of mature Merino ewes and rams (Thompson, Butterfield and Perry, 1985).

| Parameter | Gender | |
|---|---|---|
| | Ewe | Ram |
| **Mature live weight (kg)** | 51 | 69.5 |
| **Carcase weight (kg)** | 34.7 | 43.4 |
| **Muscle (%)** | 34.3 | 43 |
| **Bone (%)** | 8.2 | 9.9 |
| **Fat (%)** | 57.5 | 47.1 |

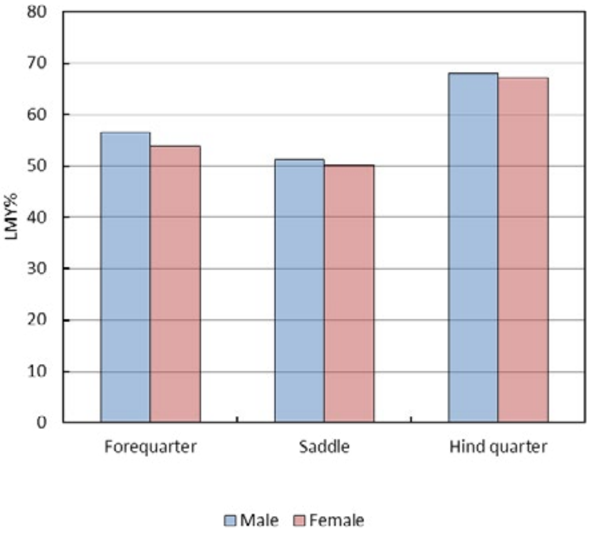
Males also mature differently to females. The major difference occurs in the neck where muscles become heavier in rams than ewes after puberty. This larger muscle mass in the neck region serves to support a larger head and for rams to exert their dominance. Rams also have less muscle in the hind region proportionately compared to ewes. Overall, rams tend to be leaner than castrated males (wethers), with the magnitude of this difference increasing with live weight or stage of maturity (Table 5).

**Table 5.** Mature body composition of rams and wethers (Butterfield et al 1985).

| Parameter | Wether | Ram |
|---|---|---|
| **Mature live weight (kg)** | 95.9 | 99.7 |
| **Head plus horns weight (kg)** | 3.4 | 6.2 |
| **Testes weight (kg)** | | 0.3 |
| **Mature live weight minus head and testes (kg)** | 92.5 | 93.2 |
| **Carcase weight (kg)** | 34.7 | 43.4 |
| **Muscle (%)** | 34.3 | 43 |
| **Bone (%)** | 8.2 | 9.9 |
| **Fat (%)** | 57.5 | 47.1 |

Irrespective of nutrition, there is a tendency for female lambs to fatten sooner than wethers and this is consistent across breed types. Carcases weighing 25kg typically contain 2-3kg less fat in wether lambs compared to ewe lambs. Other differences between wethers and ewes are not as well defined, but there is an assumption that wethers are more muscular in the cranial aspect of the carcase while ewes have more hindquarter musculature. The difference between females and males for LMY% is greatest in the forequarter region due mainly to a difference in fat rather than bone (Figure 10).

**Figure 10.** The difference in lean meat yield (LMY%) in the forequarter, saddle and hindquarter regions of male and female carcases (data from Sheep CRC Information Nucleus Flock).



### Nutrition

Alterations in growth rate due to nutrition can alter body fat and meat content and the eating quality of the meat produced. Animals experiencing periods of inadequate nutrition early in their life (prior to weaning) can be fatter post-weaning, because the growth impetus of fat is highest post-weaning. However, if sufficient nutrition is supplied early post-weaning, lambs will 'catch-up' by growing muscle and during this catch-up growth, the body puts the priority on growing carcase muscle in preference to laying down fat. Fat development may then be delayed until muscle growth has caught up to that appropriate to the animal's maturity.

### Animal health and parasites

A range of health attributes can reduce carcase weight either due to trimming affected meat tissue on the carcase, or by reducing growth during the life of the animal. These include grass seeds, arthritis, pneumonia and pleurisy.

Internal parasites (worms) can have dramatic effects on the growth of young animals. In one study, scour worm (a burden in commercial consignments of lambs in Western Australia), reduced carcase weight by about 8%. Carcase value was reduced independently of carcase weight, but the reasons for this were unclear and require further investigation. The single cell parasites cryptosporidium and giardia that live in the intestines of sheep, have also been shown to reduce carcase weight and dressing percentage.

## Genetics

### Selection for yield

There are a range of attributes that are associated with yield and these affect the trait in different ways (Table 6). Some are measured on farm, while others, including LMY%, are currently only measured after slaughter. MLA supports the Genetics Resource Flock (see Introduction) that produces lambs for detailed measurement, using semen from industry flocks. The Genetics Resource Flock enables industry sires to be assigned breeding values for these difficult to measure traits using genomic techniques based on DNA samples. More specific information about selecting sheep for different attributes can be found at http://www.sheepgenetics.org.au.

**Table 6.** Traits related to carcase LMY% & eating quality that can be used in sheep breeding programs.

| Trait | Acronym | Description | Effect of a positive ASBV on carcase |
|---|---|---|---|
| **Post weaning eye muscle depth** | PEMD | The depth of eye muscle (Longissimus dorsi) measured at the C site. | Thicker-muscled animal, higher yielding carcase that will have slightly more of its lean tissue in the higher-priced cuts. |
| **Post weaning fat depth** | PFAT | The depth of subcutaneous fat measured at the C site. | The carcase will be fatter and lower yielding. A low PFAT value is more desirable for LMY%. |
| **Post weaning weight (growth rate)** | PWT | The live weight at post weaning (225 days of age). | Faster growing, higher carcase weight and higher yielding. |
| **Intramuscular fat** | IMF% | The concentration of fat in the loin. | The meat will contain more intramuscular fat to provide more juice and flavour. |
| **Lean meat yield** | LMY% | | The carcase will be higher yielding so it will contain a high ratio of muscle compared to bone and fat. |
| **Shear force** | SF5 | The force required to slice a cooked sample of loin, measured five days post slaughter and electrical stimulation. | The meat will be tougher to eat. A low SF5 value is more desirable. |

### Single gene mutations

Specific gene mutations can increase muscling such as for the Carwell, Callipyge and Myostatin genes.  Animals that are homozygous for these genes tend to be fast growing, well-muscled and high yielding. However, there can be negative consequences associated with these genotypes, including poor eating quality due to high shear force (the meat is tough), caused by changes in the fibre characteristics of the muscle.

## Research findings

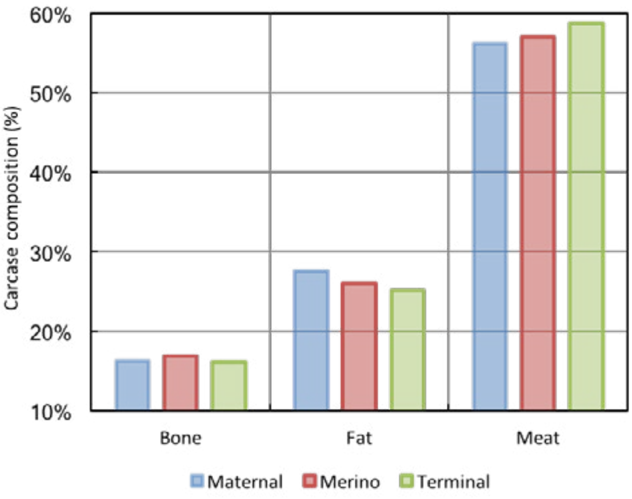
The Sheep CRC Information Nucleus Flock (INF) has provided information about the LMY% of lambs for a range of genotypes in a range of environmental conditions. This flock was operated from 2007 to 2012 at eight sites across four states in Australia. Each year over a five-year period, the same sires (more than 100) of different breeds were used to artificially inseminate ewes at all sites. In total, about 10,000 lambs were slaughtered and measured for a range of carcase and meat quality traits.

MLA continues the INF as the MLA Resource Flock at two sites (Armidale, NSW and Katanning, WA). These flocks enable the collection of animal performance traits and genomic data for the 100 industry sires of Merino, maternal and terminal breed types used each year. Measures are captured on a number of progeny per sire.

### Breed type

Differences in LMY% are observed between breeds, though these differences are small relative to the differences observed within breeds. Lambs from terminal sires had the highest yield followed by Merino and maternal breed types. This was due to a relatively higher fat content in maternal breeds and higher bone content in Merinos (Figure 11) consistent with maternal breed types maturing earlier and Merino breed types maturing later than terminal breed types. This difference was relatively consistent across the forequarter, saddle and hindquarter primal cuts.

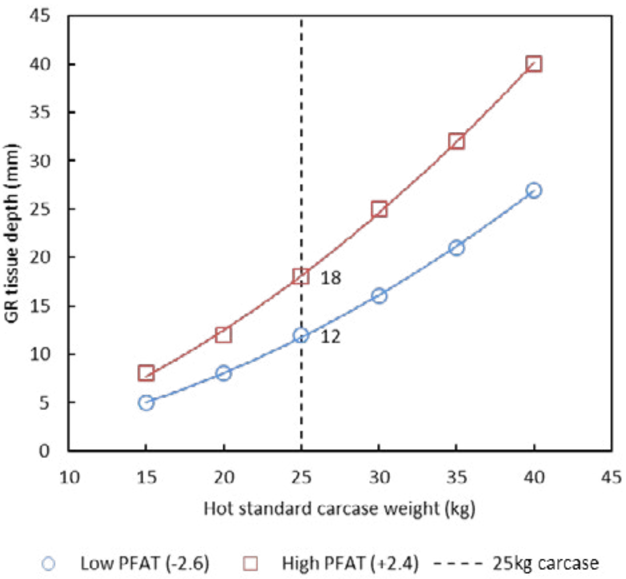
**Figure 11.** The relative proportions of bone fat and meat in carcases from maternal, Merino and terminal breed types (data from Sheep CRC Information Nucleus Flock).



### Carcase weight

As carcase size increases so does fatness (Figure 12), resulting in the LMY% tending to be lower for heavier carcases compared to lighter carcases. This depends to some extent on the breed and genetic potential of the carcase.

**Figure 12.** The association between GR tissue depth and hot carcase weight range in lambs from sires with low and high breeding values for post weaning fat depth (PFAT ASBV) (data courtesy of Sheep CRC.).



### Response to genetic selection

There are a range of traits sheep breeders can use to select animals to improve productivity. Data from the INF has confirmed that using ASBV's for muscularity or eye muscle depth (PEMD), fat depth (PFAT), and growth rate (PWT) in selection indices will change the carcase yield in a flock over time. PFAT (Table 6) had the broadest ranging effect on carcase composition of all the ASBV's tested, being consistent across all sire types.

### Post weaning eye muscle depth (PEMD)

PEMD had little impact on LMY% but did change the regional distribution of muscle – increasing the weight of muscle within the loin region. As loin cuts are highly valuable, this may increase the value of the carcase. In terminal sires the weight of the loin increased by 24.7g (7.3%), and eye muscle area increased by 0.59cm2 (4.2%) across the 4.4mm range of ASBVs for PEMD.

An increase in loin muscle weight by selecting for PEMD is likely to increase carcase value without changing overall carcase yield, given the loin is generally the highest value cut in both domestic and international markets. The lack of change in the lean weight of the hindquarter also highlights the need to find alternative ways of selecting for increased LMY% in the hindquarter, where cut values are relatively high but PEMD had little impact.

## Post weaning fat depth (PFAT)

When carcases were compared at the same carcase weight, a decreasing PFAT was associated with a decrease in all fat measures, resulting in a significant decrease in whole carcase fatness (3.7% over the PFAT range measured). There was a significant increase in the proportion of meat (9.5%) and a significant increase in loin weight and eye muscle area associated with a decrease in PFAT (Figure 13). These figures show the effect of selecting for PFAT varies according to the breed type, the tissue type and the region of the carcase. For example, if the best/leanest terminal sire (with the lowest PFAT breeding value) is compared to the worst/fattest sire (with the highest PFAT value), then there will be a 14% difference in meat on the hindquarter of their offspring. By comparison, Merino sires only produced a 6% difference in lamb hindquarter meat.

## Post weaning weight (PWT)

PWT is the live weight of a lamb at 200 days of age. Sires with high PWT produce lambs that grow faster and reach slaughter weights sooner than lambs from low PWT sires (Figure 14).

In the INF, lambs from high PWT sires had a small but significant increase in carcase lean, due to a decrease in fatness being offset by an increase in bone weight. There was, however, a significant increase in lean in the saddle region. This redistribution could be explained by maturity, with the spinal musculature being relatively early maturing. Therefore, less mature lambs should have proportionately more muscle in the saddle region than the average lamb.

There was a significantly positive correlation between birth weight and PWT, which may result in lambing difficulties in ewes mated to high growth sires. The simplest way to minimise ewe and lamb losses is to ensure terminal sires have moderate ASBVs for birth weight (BWT), visually correct shoulder/brisket structure and good ASBVs for PWT, so lambs are heavier at the same age of turnoff.

**Figure 14.** **The relationship between post weaning weight sire breeding values and lamb hot carcase weight. ○ Terminal sires; ☐ Maternal sires; and Δ Merino sires (Data courtesy of Sheep CRC).**

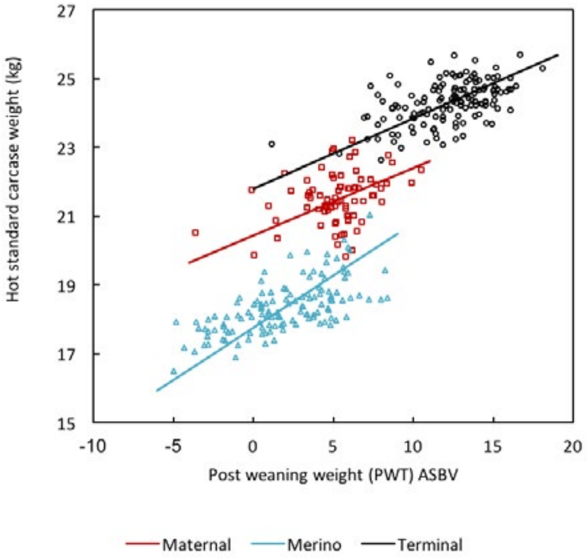
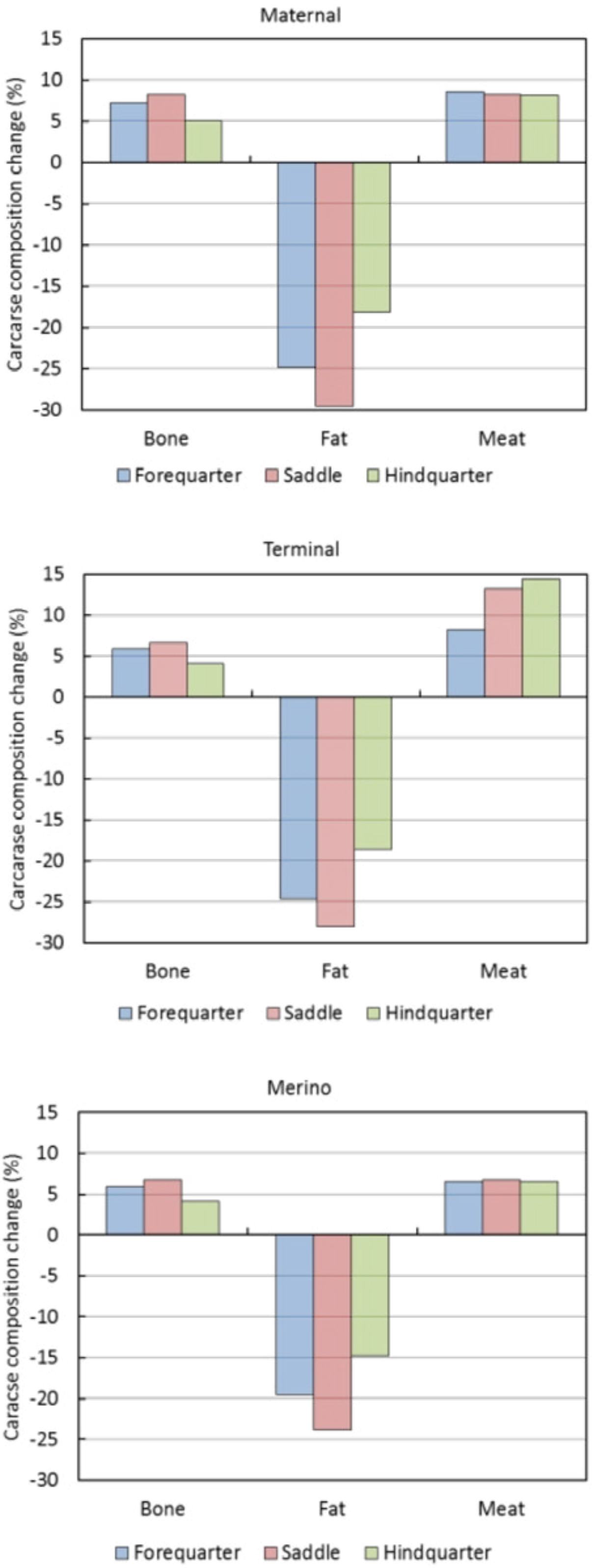


**Figure 13.** **The effect of selecting for PFAT on carcase composition for maternal, Merino and terminal breed types in the forequarter, saddle and hindquarter regions. The bars represent the percentage change in bone, fat or meat in each region across the range in sire PFAT breeding values in the Sheep CRC Information Nucleus Flock.**



### ASBVs for LMY% and eating quality

ASBVs for eating quality (IMF and SF5) and lean meat yield (LMY %) are now available for Merino, Border Leicester, Poll Dorset and White Suffolk breeds. Genomic information using a 15k SNP chip analysis and measurements from related animals in the Sheep CRC Information Nucleus and/or MLA Resource Flocks support these values.

Incorporating eating quality and yield breeding values into selection decisions when choosing sires, allows animals to be selected directly for meat and carcase quality traits. Higher or more positive intramuscular fat (IMF) breeding values are favourable. Lower or more negative shear force (SF5) values are favourable. Higher or more positive lean meat yield (LMY%) and dressing percentage (DRESS) values are favourable.

### Lean meat yield (LMY%)

This trait is a measure of the commercial yield of lean meat as a percentage of hot standard 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 high heritability, with the normal range in lamb being between 51% and 58%. The ASBVs are spread around 0, with higher values indicating greater genetic potential for higher LMY%.

### Intramuscular fat (IMF%)

This trait is a measure of the chemical fat percentage in the loin muscle of a lamb, and the visible component is known as marbling. IMF has been shown to have a large effect on the sensory characteristics of lamb, including flavour, juiciness, tenderness and overall liking. The preferred level of IMF in lamb meat is between 4% and 6%, with a current industry mean value of 4.3%. The IMF range in Information Nucleus Flock lambs was between 2% and 7%.

IMF has a moderate to high heritability and a high negative correlation with shear force, that is, how hard it is to cut through the meat (see below). Therefore, as IMF increases, shear force reduces and tenderness increases. The sire breeding values for IMF are spread around 0, with higher values indicating a greater genetic potential for higher IMF%.

### Shear force (SF5)

Shear force is a guide to the consumer perception of tenderness and is the force required to cut through a cooked sample of meat using a standardised cutting blade after five days ageing (SF5). For this trait, shear force is measured in the loin muscle five days after slaughter to allow for tenderisation due to proteolysis that occurs with ageing.

The heritability of this trait is moderate to high. Lower shear force values represent more tender meat, with shear force of 3kg or less sought in lamb loin to achieve tenderness. The mean SF5 from the INF lambs was 2.4kg, with a range from 1.1kg to 7.7kg. Lower ASBV values indicate greater genetic potential for lower SF5 and more tender meat.

## Practical steps

### Monitor carcase data

### 1. Dressing percentage (DRESS)

DRESS is generally unrelated to LMY%, so a high dressing percentage (DP) won’t necessarily correspond to a high carcase yield. The breeding value for DRESS can be used as a tool to make judgements on the best time to send lambs to slaughter. It is useful to determine DRESS under controlled curfew conditions for your flock and to use a standard time off feed prior to weighing, as DP can vary between farms and breeds. The carcase weight can be calculated from the live weight and the estimated DP. The date of lamb delivery to achieve the targeted carcase weight for a grid can then be calculated from the expected carcase weight and lamb growth rate. Marketing lambs at the correct weight and fat score will enhance the chance of achieving the best price at slaughter.

## 2. Carcase feedback information

Abattoirs generally will report carcase data back to the producer when lambs have been sold directly to the abattoir (over the hooks). The system used will depend on the abattoir. MLA has developed a system called Livestock Data Link (LDL) that is available on its web page (Figure 15).

LDL currently offers two modules:

1. Carcase compliance – users can analyse carcase performance in terms of compliance to the grid they consigned against, with performance outcomes linked to a library of solutions on how to address non-compliant issues on farm.
2. Animal health information – users can view any animal health conditions identified as part of post-mortem inspection. Please note the current functionality relates only to sheep health data collected through the National Sheep Health Monitoring Project.

Further data management and feedback systems are being developed as part of the ALMTech project.

## Use selection indices to improve yield

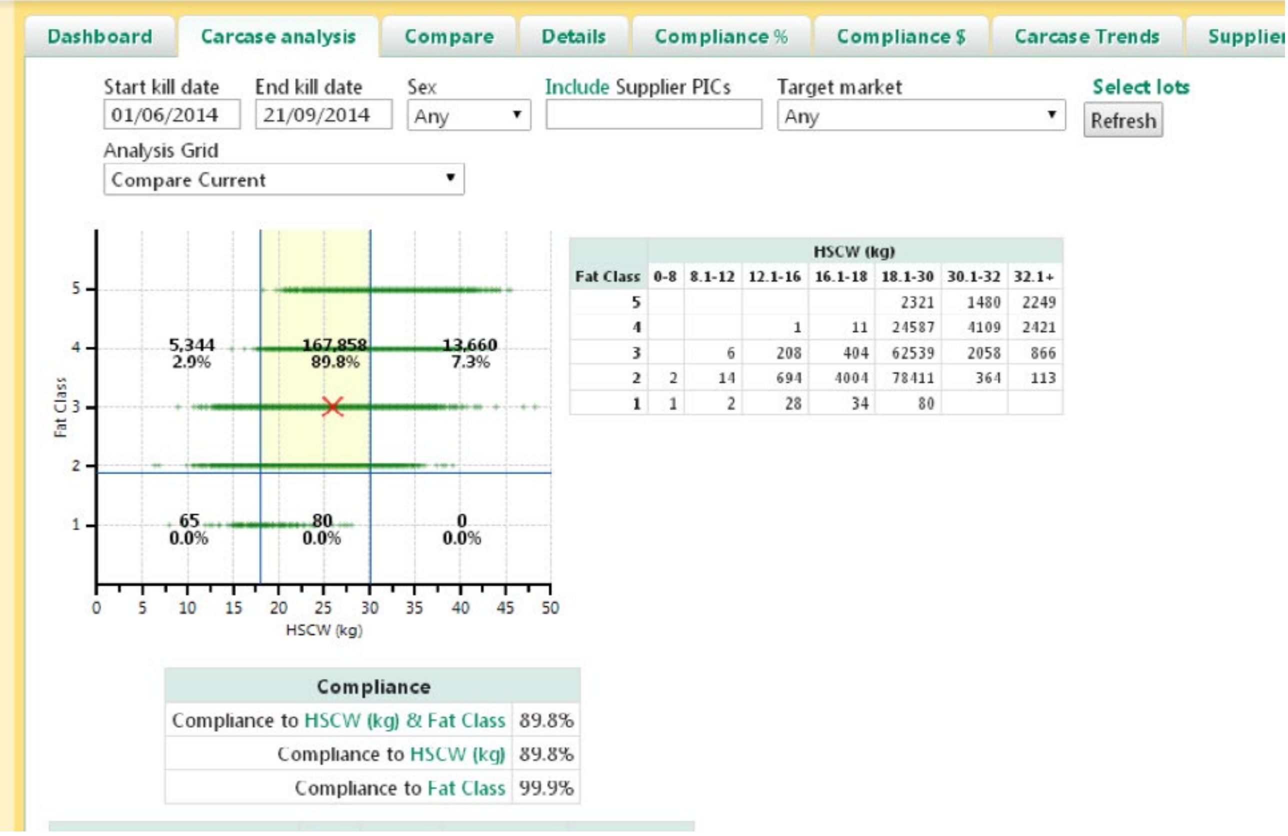
ASBVs can be used to improve traits, although other factors such as nutrition will also play a role. LMY% can be improved by using the LMY% breeding value. PWT, PEMD and PFAT are correlated to LMY% and these traits can also be used to improve LMY%.

Selecting for more than one trait can make it challenging to get the balance between traits right, as many are related. Selection indexes have been developed to manage the relationships between traits and assist with balanced selection. This is important for balancing LMY% with eating quality traits.

> Commercially used indexes for improving LMY% include the Lamb 2020 Index, the Carcase Plus Index and the Trade and Export $ Indexes. Selecting rams with higher values for these indexes will have a very positive effect on the LMY% of the progeny. However, these indexes will reduce meat eating quality. To overcome this problem, new indexes (Eating Quality and Lamb 2020 Eating Quality) that select for higher LMY% and for eating quality traits (including IMF and SF5) have been developed.

Sheep Genetics (http://www.sheepgenetics.org.au) provides some specifications and general recommendations for cut-offs and selection criteria on a range of ASBVs for producers, along with reasons for the recommendations (http://www.sheepgenetics.org.au/Getting-started/ASBVs-and-Indexes). It is important to understand these are general guidelines and breeders should adjust for their personal situation and consult with their ram breeders to determine the most appropriate sire selection.

**Figure 15.** LDL web page example.



Start kill date: 01/06/2014
End kill date: 21/09/2014
Sex: Any
Include Supplier PICs:
Target market: Any
Analysis Grid: Compare Current

| Fat Class | HSCW (kg) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0-8 | 8.1-12 | 12.1-16 | 16.1-18 | 18.1-30 | 30.1-32 | 32.1+ |
| 5 | | | | | 2321 | 1480 | 2249 |
| 4 | | | 1 | 11 | 24587 | 4109 | 2421 |
| 3 | | 6 | 208 | 404 | 62539 | 2058 | 866 |
| 2 | 2 | 14 | 694 | 4004 | 78411 | 364 | 113 |
| 1 | 1 | 2 | 28 | 34 | 80 | | |

| Compliance | |
|---|---|
| Compliance to HSCW (kg) & Fat Class | 89.8% |
| Compliance to HSCW (kg) | 89.8% |
| Compliance to Fat Class | 99.9% |

# Chapter 2. Path to slaughter

## Value proposition – know your path

The path to slaughter can affect the value of lambs. There is, however, little information on the effect of different paths on LMY%. So, the decisions about the path to slaughter can really only be made in relation to the effects on carcase weight, but these are well documented. The path to slaughter that takes the least time will result in the least weight loss and carcase weight is an important determinant of carcase value. The path to slaughter can also affect the eating quality of meat and needs to be considered to achieve the most valuable carcase in terms of both carcase weight and eating quality.

## Key principles

### Animal effects

The path to slaughter varies and will include some or all of the following steps: mustering, yarding, transport, saleyards and lairage. The management of lambs during this period requires fasting and water deprivation to avoid soiling on trucks, subsequently degrading the skin value and contaminating the carcase at slaughter.

Fasting and water deprivation reduces the amount of material in a lamb's gut and the amount of urine in its bladder. However, there is a limit to the usefulness of this as a management procedure, with its advantage reducing with increasing time off feed or water.

Furthermore, the effect of feed and water deprivation is not limited to the contents of the gut and the bladder. Physiological mechanisms that enable the lamb to maintain bodily functions during this period result in changes to body tissues particularly muscle.

### Time of monitoring

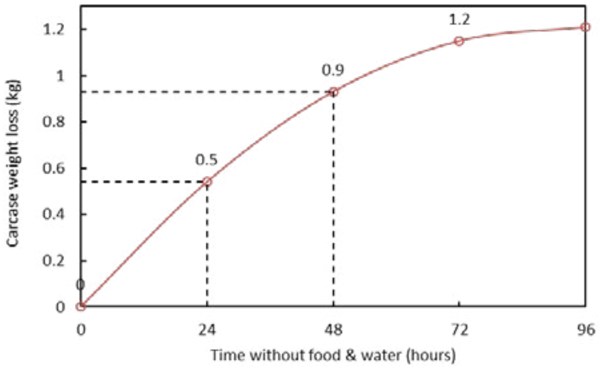
Due to the effect of feed and water deprivation on gut and urinary bladder contents, the timing of key measurements, such as live weight during the curfew period, can be important. Live weight will vary according to the length of the pre-slaughter period and attributes that depend on live weight, such as dressing percentage, will vary accordingly. For this reason, standard curfew periods are useful when monitoring such factors.

## Research findings

### Effects of time off feed and water on carcase weight

- The length of the fasting time in total during the path to slaughter varies from about six to 72 hours, depending on practical considerations and commercial decisions made along the way. Water may also be withheld during some or all of this time.
- To avoid dehydration of tissues, the body responds firstly by increasing urinary concentration to reduce the loss of fluid. This occurs about 24 hours after water has been withheld. However, by 48 hours this mechanism is no longer sufficient, and the effects of dehydration start influencing the amount of water present in muscle. This reduces muscle weight and carcase weight.
- The length of feed and water deprivation is the main factor to consider during the path to slaughter. The type of activity undertaken during this period (e.g. transport), is not as important as the length of time itself. Stress and excessive exercise during this period can exacerbate dehydration and muscle glycogen loss and be detrimental to eating quality.
- The relationship between weight loss and time off feed and water tends to be curvilinear, starting fast and then slowing down later in the period (Figure 16). This is due to both water and tissue loss.
- Fat score also decreases with the length of time taken for the path to slaughter. This relationship is more of a straight line (constant rate of decline).
- Water loading strategies prior to the pre-slaughter period have been tested to reduce the effect of dehydration, including the use of proprietary electrolyte mixtures. Generally, these have not improved hydration status at the time of slaughter, with the exception of a high sodium intake acquired from grazing salt land pastures. However, this can increase urine output, so curfews need to be observed.
- Water deprivation for 48 hours causes a reduction in muscle fibre size and muscle water content.
- Recovery of carcase weight following feed and water deprivation can take up to 96 hours.

**Figure 16.** The effect of the time in hours without food and water on hot carcase weight (adapted from Thompson et al 1987).



## Practical steps

### Limit the length of the fasting period

Fasting is a factor common to all of the stages along the path to slaughter. Reducing the length in total, including the curfew period on farm, will minimise the effect of feed and water deprivation on carcase weight and condition score. There are regulations about the maximum times allowable for feed and water deprivation during transport and lairage. These can be found in the National Model Codes of Practice for the Welfare of Livestock and have been adopted by organisations such as the Australian Livestock and Rural Transporters' Association (ALRTA). Details can be found on the website – http://www.agriculture.gov.au/animal/welfare/standards-guidelines.

### Carcase weight

The total length of time without food and water should be as short as practicable within the limits of curfew. Fasting and water deprivation reduce carcase weight mainly due to muscle dehydration, and to a lesser extent, fat mobilisation when the period is extended. The single most important factor is the length of time off feed and water, with the activities that might occur during this period, such as transport, being largely immaterial to the effect on carcase weight. For lambs, the rate of loss of carcase weight is about 0.1% per hour of fasting, although the rate slows as the fasting time increases. For example, reducing time off feed in slaughter lambs from 48 to 36 hours equates to about 0.24kg of extra carcase weight. If carcase price was $6.00 per kg, the financial gain of reducing fasting by 12 hours would be $1.44 per carcase.

### Dressing percentage

The longer the fasting period the lower the weight of gut contents or gut fill, the lower the live weight and the higher the dressing percentage. Longer fasting increases dressing percentage due to greater reductions in live weight than in carcase weight. This effect should be factored in to the calculation when using dressing percentage to estimate carcase weight. Details on how to adjust dressing percentage according to the time off feed are detailed at https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/minlrs-information-brochures-etc/mla_sheep-assessment-manual_jan-2017.pdf

### Observe curfews

Reduced gut fill and the subsequent soiling of lambs with faeces and urine is a mandatory requirement for the marketing of lambs. Overseas markets in particular have zero tolerance for these contaminants. Carcases that have been contaminated will be trimmed to remove the contamination and this will reduce carcase weight. So, whilst choosing the shortest path to market is worthwhile, curfews should also be met for hygiene reasons.

### Avoid injuries

Injuries sustained during transport from farm to abattoir can result in bruises or traumatic injuries such as broken legs. Trimming to remove damaged portions of carcases reduces carcase weight and value. Dogs should be muzzled and facilities such as yards and trucks should have no sharp edges or objects that can cause injuries. Faulty flooring that traps lambs' feet can also lead to injuries and lameness, resulting in lambs being unfit for travel or slaughter.

### Access to water

Access to water during the lairage period will reduce the loss associated with dehydration. For lambs, reluctance to drink in unfamiliar surroundings may contribute to dehydration. Nevertheless, access to water should be provided where possible and when appropriate in accordance with any curfew requirements.

# Chapter 3. Slaughter

## Value proposition for processors – know your carcase

Slaughter is a strategically important time to measure LMY% of individual carcases. This data can be used to determine the value of a carcase, provide feedback to farmers and genetic databases and has synergies with automation. Sheep processors currently measure carcass weight, animal age via dentition and fat score via physical palpation, as these are the most simplistic and common language terms used to categorise and trade sheep carcasses. Most processors support the development of objective measurement technologies for sheep carcases if they can meet their commercial needs.

### Better lambs

When producers have data available to them that has been collected from their lambs, they have the opportunity to recognise any need for improvement in their own flock. With subsequent improvements, they will present better lambs to the processor and have better compliance rates with grid specifications into the future.

### Automation

Measurement can be synergistic with automation in meat processing. Automated cutting machines use imaging systems that map carcases in real time to direct the cutting blades. Data from these images can be used to calculate LMY%. For example, Dual Energy X-ray Absorptiometry (DEXA) prediction of LMY% was developed as a modification to an existing robotic system that uses 2D X-ray images to identify cutting lines in lamb carcases. Digital data capture also enables reporting up and down the supply chain in real time.

## Key principles

### Measuring LMY%

### Ideal attributes for in plant measurement

Measurement in plant is essential for LMY% to be used as a management tool in real time across the supply chain. To achieve this, the technologies can vary, but should aim to have the following attributes:

1. Operate at chain speed (up to 14 lambs/minute)
2. Be non-invasive and cause no damage to the carcase
3. Provide accurate, precise and repeatable prediction of LMY% (± other traits)
4. Be robust enough for use in the wet environment of a slaughter floor
5. Be commercialised by a reputable company with excellent backup and service
6. Can be linked to data recording and reporting systems
7. Can be used to measure hot or cold carcases depending on the application
8. Be suited to automation

### Gold standard

A range of measurement technologies can be used to measure LMY% and these vary in accuracy and precision. A gold standard measure of LMY%, that has the best accuracy and precision characteristics possible to compare the different technologies against, is needed. The gold standard is also needed to research and report on the different measurement technologies available, but it does not necessarily need to be applicable for commercial use in the plant, (e.g. in terms of robustness and speed of measurement).

Internationally, two systems are used as gold standards for the measurement of carcase composition: Computed Tomography (CT) scanning (Figure 20) and chemical composition. Determining chemical composition requires the whole carcase to be ground up, sub-sampled and analysed chemically. This is a difficult and expensive method that destroys the carcase, so the procedure cannot be repeated.

Carcases can be repeatedly CT scanned, meaning the high repeatability of CT LMY% can be demonstrated, as opposed to using chemical analyses. For these reasons, CT scanning is used as the gold standard for measuring lamb LMY% in Australia and provides the LMY% value that all other technologies are then trained on (i.e. the algorithms developed for other technologies to predict LMY% are trained on CT LMY%). The mechanics of these systems is discussed in further detail in the section about the whole carcase.

### Measurement systems vary between animal species

Differences between animal species make it difficult to develop the same machinery for all types. For example, the skin is removed when sheep and cattle are processed, but not in the case of pigs. Some technologies developed for pig carcases, such as ultrasound and electrical impedance, are not suited to sheep and cattle carcases for this reason.

### Technologies to measure LMY% in sheep carcases

The Australian lamb industry has been assessing and developing a number of different techniques to measure LMY% with a number of commercial partners. There are two main categories of measurement techniques: site measurement and whole carcase measurement.

## Single site measurement

Traditionally, LMY% has been predicted using systems that measure tissue at a single site on the carcase (Figure 17). The LMY% of the carcase is then predicted using algorithms that relate the tissue measurement to LMY%. The systems used to measure tissue at a single site include: specialised knives, mechanical probes, electrical impedance probes, cameras and ultrasound systems.

The dimensions of interest are commonly tissue depths or muscle area at the following sites:

- GR site (110mm from the carcase midline over the 12th rib)
- C site (45mm from the carcase midline at the 12th/13th rib), and the
- loin muscle at the C site.

The advantage of single site systems is that they are relatively simple and do not require automation. Although this lack of automation may require a labour unit to operate, the relatively low cost of installing these systems makes them suited to small abattoirs. For this reason, development of single site systems is being continued by the Sheep CRC.

The major limiting factor of these systems is the distribution of fat and meat tissue in a carcase can be quite variable. A measurement at a single site may not always provide an accurate prediction of the total amount of fat or meat that determines LMY%, due to the variation of tissue distribution within a carcase. The accuracy of prediction of LMY% using these systems can be low even when the dimension of interest has been measured accurately.

For systems that are done manually, such as palpation, differences between operators can also be a source of error. Technologies such as microwave that measure tissue depths at multiple sites to predict LMY% are being developed and may improve the accuracy and precision of the LMY% estimate to some extent, while maintaining the advantages of being low cost and simple to operate.

**Figure 17.** The cut surface of a loin showing the different dimensions of fat and muscle tissue at this site for a low (bottom loin) and high (top loin) LMY% carcase.

## Whole carcase measurement

Modern imaging technology makes it possible to use the entire carcase for LMY% measurement. The accuracy and precision with which these technologies can measure LMY% depends on the type of imaging used. Video Image Analysis (VIA) and 3D imaging systems scan the external surface of the whole carcase and use information on fatness and conformation to predict LMY%.

Alternatively, imaging technologies such as Dual Energy X-ray Absorptiometry (DEXA) and CT use X-rays to penetrate the carcase and determine quantities of bone, fat and meat, providing a more accurate and precise measure of LMY%. These whole carcase systems avoid the sampling error associated with single site measures. Rather than relying on just one tissue type (such as fat) to predict LMY%, the predictions are based on the three tissue types: bone, fat and meat. These systems are inherently more expensive, but can be automated or be part of an automated cutting system.

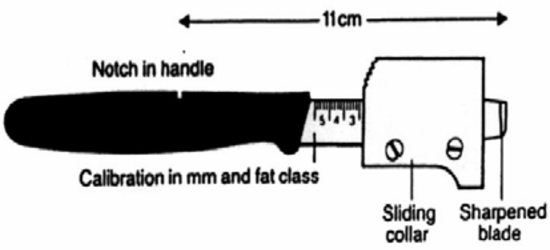
## Single site systems for LMY% measurement

Single site systems use a measurement of tissue composition taken at one point in a carcase (e.g. the GR site), and then rely on an algorithm to derive a predicted value. The algorithm generally has been formulated from the gold standard (CT scanning).

## GR tissue depth

The GR Knife is a simple device that is a combination of a ruler and knife (Figure 18). Tissue depth is measured at the GR site located at the 12th rib and 110mm from the midline. Although this is an improvement on manual palpation, GR tissue depth is also influenced by operator error, especially as it is routinely measured on hot carcases before the fat has 'set' and precision is reduced when used at higher chain speeds. Both fat and muscle are included in the tissue depth measurement. The GR knife is a pragmatic measure but requires an operator and is slow.

**Figure 18.** GR knife for use measuring GR tissue depth.



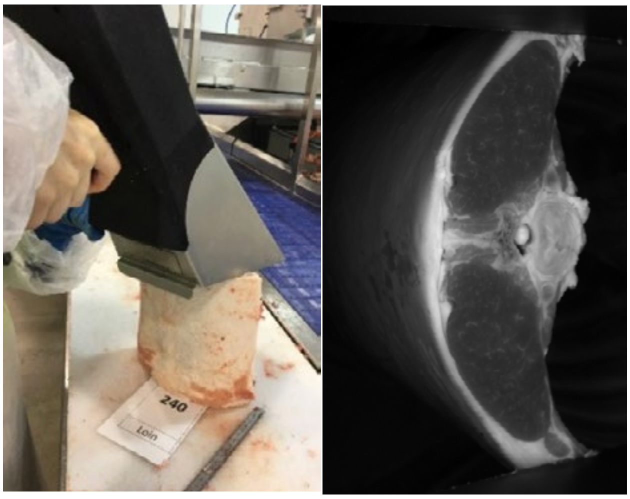
### Cut surface imaging

Imaging technologies such as hyperspectral imaging are being investigated for use on a cut loin surface to measure tissue depth at the GR and C sites, and the area of the loin muscle to predict LMY%. Imaging of the cut loin surface may also be used to determine important eating quality traits such as intramuscular fat content and meat colour.

These imaging technologies have the potential to provide a system that can predict both the yield and eating quality of a carcase. As a cut or prepared loin surface is essential for this technology, this type of system would be employed at the point of carcase splitting.

This may be too late in the process for carcase sorting but would provide information for the purpose of producer feedback. The testing of prototype hyperspectral imaging cameras began in 2015 (Figure 19).

**Figure 19.** **Frontmatec hyperspectral imaging camera and image of the loin (Photos courtesy of Frontmatec).**



### Other technologies

Technologies such as ultrasound, microwave and probes have been investigated for the measurement of fat depth at single or multiple sites in lamb carcases. Though ultrasound technology has been successfully developed to measure the back fat of pigs, the different dressing procedures in lamb has prevented successful ultrasound measuring of fat depth and predicting the LMY% of lambs.

Microwave technologies are currently being tested and are showing great potential for measuring fat depth at multiple sites on a lamb carcase. Portable microwave devices may provide an inexpensive means of predicting LMY% that is more objective and precise than manual single site tissue measures.

The Ausmeat Probe was a successful way of measuring GR tissue depth but is no longer in production. The Icelandic Tissue Probe is a similar device used by the sheep industry in Iceland and is currently being tested for Australian conditions.

### Whole carcase systems for LMY% measurement

Whole carcase systems measure tissue composition in many places across the carcase and do not rely on a prediction algorithm. They are able to quantify more sources of variation and be more precise compared to single site measurement systems.

### Dual Energy X-Ray Absorptiometry (DEXA)

DEXA can precisely and accurately predict the LMY% of lamb carcases using X-rays that penetrate the carcase to produce a 2D image. Fat, meat and bone have different densities, which influence the penetration of X-rays through these tissues. The DEXA system produces two X-ray images, the first captured from low energy and the second from high energy X-rays.

The difference between these two images allows the three tissue types (bone, fat and meat) to be distinguished. Lamb carcases may be scanned hot or cold for DEXA determination of LMY%. Testing of an on-line DEXA system demonstrated the capability of predicting CT-determined LMY% with high repeatability, accuracy and precision.

The DEXA system may also be used to accurately predict the weight of saleable cuts of meat. DEXA systems have the potential to scan up to 30 carcases per minute – well beyond the fastest chain speed of any Australian lamb abattoir. The disadvantages of the DEXA system are the space requirements in the abattoir and the installation costs.

### CT (computed tomography) scanning

CT is a medical imaging technique that uses low dose X-rays to image the body in cross-sections and provide a 3D image of the body. This visual imaging of the internal structures of a carcase can differentiate tissue types with very high accuracy and precision (Figure 20).

CT scanning can measure LMY% with high precision, accuracy and repeatability. Carcase composition can be determined from just a limited number of cross-sectional scans of the forequarter/chest region, the loin and the hind leg, or more comprehensively, from multiple adjacent scans extending the entire length of the body. This highly accurate predictor of carcase composition can also be used to measure the muscling in different parts of the carcase, such as the rib, loin and legs.

CT scanning is considered as the gold standard for LMY% measurement, against which other technologies for LMY% prediction can be compared, trained and validated. While the speed and expense of CT scanning currently limits its use in industry, novel CT technologies being developed could make line speed CT scanning a commercial reality in the future.

**Figure 20.** A lamb carcase being CT scanned to determine its lean meat yield and a cross-section CT image of a lamb fore section where the bone (white), meat (light grey) and fat (dark grey) can be clearly differentiated.

### Chemical composition

Prior to the development of CT scanning, chemical assays were considered the gold standard for measuring the composition of carcases. To determine the chemical composition of a carcase, the entire carcase must be ground into a homogenous mixture that is then sub-sampled for chemical analysis.

A series of chemical tests measure the amount of fat, protein and ash in the representative sample to determine the relative proportions of fat, muscle and bone in a carcase. While chemical assays can determine LMY% with high precision and accuracy, the repeatability of the measure cannot be determined, as the carcase is destroyed in the process of obtaining the measurement.

The destruction of the carcase also means that chemical assays are an expensive means of determining LMY%. Computed tomography has therefore replaced chemical assays as the gold standard for LMY% determination.

### Other technologies

Technologies such as Video Image Analysis (VIA) and 3Dimensional (3D) imaging may also be used to provide whole carcase estimates of LMY%. VIA systems estimate carcase composition based on the external conformation of a carcase. These systems consist of a booth, an artificial light, high quality digital camera and a computer program that analyses the images and extracts carcase measurements.

Commercial VIA systems have included the VIAscan®, E+V, the Lamb Vision System and the Carometec BCC system for beef. A novel 3D imaging device has been under evaluation in 2018 and 2019 for its capacity to predict CT composition by scanning live animals and carcases.

An advantage of these systems is the lack of human operator error compared to measures such as GR, and the smaller footprint compared to tools such as DEXA. While VIA systems have only been shown to predict CT LMY% with moderate precision (Figure 21), the lower expense and smaller footprint of these devices enables smaller scale processors to have a predictive LMY% tool.

## Research findings

### Methods of LMY% measurement

Many different methods exist to predict or measure LMY% (Table 7). These methods range from very simple traditional methods such as manual palpation, where fatness at a single site is used to estimate LMY%, through to highly advanced technologies such as CT or computed tomography scanning that produces a complete 3D dissection of a carcase.

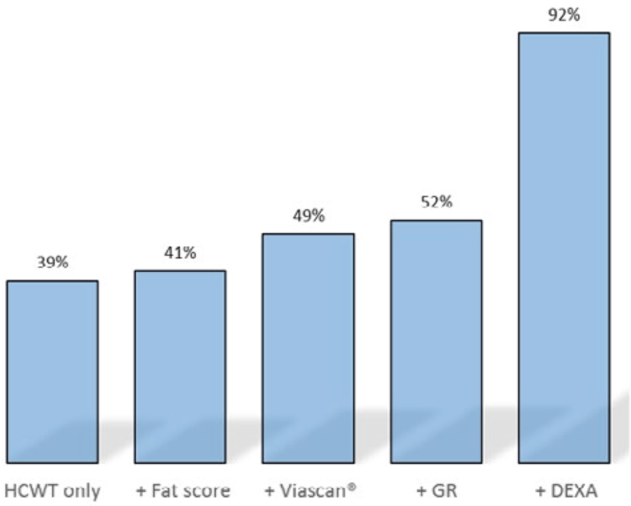
**Table 7.** Examples of the range of traditional and advanced measurement technologies used or being assessed for use to measure lamb carcases and estimate LMY%.

| Application | Method |
|---|---|
| **Traditional methods** | |
| **Live lamb on farm** | Manual palpation |
| | Ultrasound |
| **Carcase** | Manual palpation (fat score) |
| | GR tissue knife |
| | Viascan |
| | Mechanical probes |
| **Advanced methods** | |
| **Live lamb on farm** | CT |
| | Microwave |
| **Carcase** | DEXA |
| | CT |
| | Multi-spectral camera |
| | Microwave |
| | 3Dimensional imaging |

### The precision of LMY% measurement devices

The precision of measuring LMY% increases as the technique moves from measuring fatness at a single site, to multiple sites, to imaging the external surface of a carcase, to imaging the internal composition of a carcase (Figure 21).

**Figure 21.** The precision (R-squared) of different measurement systems for estimating the gold standard of CT LMY%. (Data courtesy of Sheep CRC).



### Traditional measurement systems have low precision and accuracy

Traditional methods used to grade carcases have mostly been based on a measurement of carcase fatness as a proxy for LMY%. Sheep CRC research has shown these methods are often imprecise and inaccurate.

The reasons for imprecision vary, but include:

- Subjective bias of an operator (human error)
- Data is collected from one tissue only (such as fat), rather than the three tissues of bone, fat and meat
- Data is collected from only a single site on a carcase (e.g. loin).

As an example, carcase weight and fat score alone are poor predictors of LMY%. The technique for fat scoring is prone to inaccuracy and the method does not include estimates for bone and muscle tissues. Whilst grids assist with processing efficiency, the value of this information to producers for improving LMY% is limited and more sophisticated methods are required if LMY% is to be used to estimate carcase value.

### Eating quality & LMY%

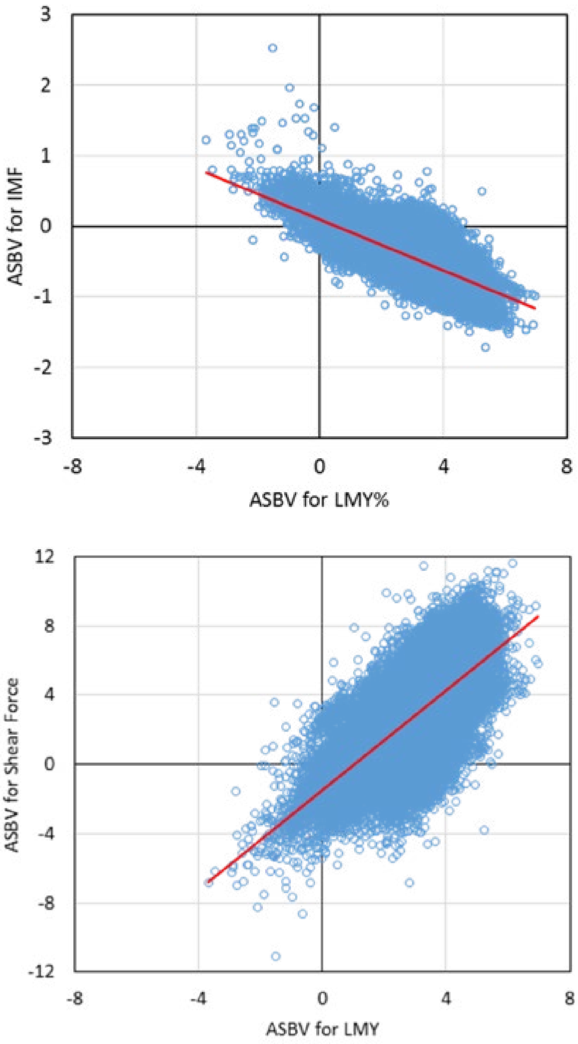
An extensive sensory analysis was conducted on meat from lambs bred in the Sheep CRC Information Nucleus Flock (INF) program. This has provided a thorough understanding of the sensory attributes valued by consumers and how sires can be selected to achieve these attributes.

A key conclusion from these results is the importance of a balanced approach. When selecting to increase LMY%, producers should not lose sight of meat quality traits and human health benefits of lamb meat. Very lean, highly muscled animals may guarantee high LMY%, but these animals may be less desired by consumers.

For example, lean animals tend to cool more rapidly and be susceptible to 'cold shortening' during refrigeration. Cold shortening occurs when, prior to the onset of rigor mortis, carcases are subjected to rapidly lowered temperature which toughens muscle and disappoints consumers.

IMF is a key driver of the sensory attributes of tenderness, juiciness and flavour, and a benchmark of 4%-6% IMF or above is required to achieve a premium eating quality experience. The mean value for IMF in the loin of the lambs slaughtered from the Sheep CRC INF was 4.2%. Two weeks of weight loss prior to slaughter can reduce IMF by 1%. A change in fat score of 1 correlates to about 0.2% change in IMF and a 1kg change in HCW correlates to about 0.07% change in IMF.

**Figure 22.** The relationships between sire breeding values for LMY% and for eating quality traits IMF and SF5.



## Practical steps

### Carcase data management/systems

Improved measurement of carcase LMY% will improve the feedback provided to producers and the ability of processors to add value to their business. However, the effective flow of LMY% data will require effective data management and delivery systems to be in place. Individual carcase identification or tracking in the abattoir will be central to optimising the value of the LMY% data.

### Feedback to producers

LMY% data based on GR knife measurement is currently fed back to some producers through data capture and reporting systems such as Livestock Data Link (LDL) and other company-based systems. This LMY% value can be updated as more precise and accurate means of LMY% measurement such as DEXA become more readily available to producers. The development of a Meat Standards Australia (MSA) system for sheep meat will also provide the opportunity for carcase data to be fed back to producers. Improved LMY% and eating quality information provided by technologies will be built into the MSA system.

### On flow of data to boning room for optimisation

Improved LMY% data provides an opportunity to improve the boning of lamb carcases. Tools such as the Lamb Value Calculator (Figure 32) demonstrate precise and accurate LMY% information can be used to predict the cut weights of carcase and in turn determine the best way to cut the carcase to optimise gross profit margins.

### Spray chilling carcases

Spray chilling is the intermittent spraying of carcases with water to minimise carcase weight loss (shrink) during the first few hours of carcase chilling. Spray chilling reduces the average carcase weight loss during overnight chilling from around 3% to 0.6%. As carcase weight is not lost evenly from all muscle tissues during chilling, spray chilling also impacts carcase yield. A yield trial comparing sprayed and non-sprayed carcases from the same chiller indicated spray chilling resulted in an extra 2.3% of saleable meat.

# Chapter 4. Retail

## Value proposition for retail – know your cut

Optimising carcase deboning or cut fabrication and the support of high value brands are ways that information about LMY% can be used to increase the value of lamb meat at the retail end of the supply chain.

### Cut fabrication

Cut fabrication involves converting a carcase into cuts for retail sale, which is often referred to as being 'case ready'. Traditionally this process was done in the butcher shop, but it is increasingly being done in centrally-based deboning rooms. The differences in scale of operation can result in different applications of LMY% to the business. However, LMY% can be used to optimise the value of carcases in many ways:

1. Carcases can be chosen so the amount of fat trimmed for waste is minimal. If 5% of the carcase is trimmed off as fat, this will reduce the weight of saleable meat by a corresponding amount.
2. The cutting specifications can be changed so the proportion of carcase weight can be included into high priced cuts (i.e. rack is priced as high as possible). The retail value of a carcase will depend on the relative weights of low and high value cuts derived from the carcase.
3. Carcases can be sorted into groups that have the same cutting specifications. This improves the efficiency of the boning operation.
4. The product line can be kept as uniform as possible to satisfy the needs of customers for high value brands. By knowing the LMY%, greater consistency can be achieved for the weight, shape and dimensions of the various cuts prepared for retail.

### High value brands

High value carcases will have attributes that are valued by the customer. Studies have shown consumers are willing to pay more for cuts that have a high meat component and high eating quality. If carcases that meet such criteria can be identified by measuring factors such as LMY% and IMF, cuts from these carcases can be/will be branded as premium to achieve a higher price.

## Key principles

### High LMY% carcases have less fat

The higher the LMY% the lower the amount of fat in the carcase and the lower the amount of material that needs to be trimmed for waste, so a high yielding lamb will have low quantities of fat externally and between muscle groups (seam fat). For example, a carcase will have a GR tissue depth about 5mm when LMY% is 60%, compared to 25mm when LMY% is 50%. It is important to bear in mind these are average figures and the variation around these figures is what makes GR tissue depth a poor predictor of LMY%.

### Cut weights and dimensions depend on LMY% as well as carcase weight

The weights of primal cuts depend on the carcase weight and the LMY% of a carcase. Choosing a large carcase will not necessarily result in large cuts if the carcase has a low LMY% and vice versa.

Extensive carcase data from the Sheep CRC INF has been used to characterise the mathematical relationships between LMY%, carcase weight and cut weights. These relationships have been incorporated into the Lamb Value Calculator which allows the expected cut weights to be predicted from these basic inputs. More precise measurement of LMY% using whole of carcase imaging technologies such as CT scanning and DEXA has allowed very precise prediction of individual cut weights. This will allow for better commercial decisions to be made around carcase selection and fabrication specifications to achieve the most profit.

### IMF is most important for eating quality in high LMY% carcases

There is a negative correlation between LMY% and the eating quality of meat from a carcase. In general terms, the higher the LMY% the lower the eating quality attributes of tenderness, juiciness and overall liking. For this reason, retailers should be aware of eating quality as well as LMY%. In particular, intramuscular fat (IMF) becomes increasingly important for eating quality in higher yielding carcases.

Eating quality is an important point of difference for red meats (beef and sheep meat) compared to white meats (pork and chicken). This is because ruminant animals (sheep and cattle) are relatively more expensive to produce than monogastric animals (pigs and chickens).

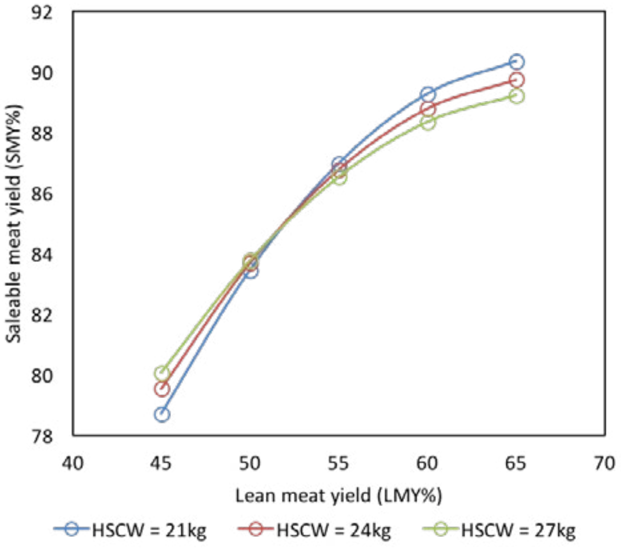
This means eating quality is as important as improving efficiency through LMY% to justify to consumers the price premium for red meat.

## Research findings

### SMY% increases with LMY%

SMY% is always greater than LMY% because some bone and fat are included in commercial cuts (saleable meat) in addition to meat. Increases in LMY% provide greater increases in SMY% when the increases are in the range of 45% to 55% LMY%, than for 55% to 65% LMY%. This response depends to some extent on carcase weight and is greater for lighter carcases than heavy carcases (Figure 23). For carcases with a low LMY% (45%), a high carcase weight will provide the best SMY%. However, for carcases with a high LMY% (65%), a low carcase weight will give the best SMY%.

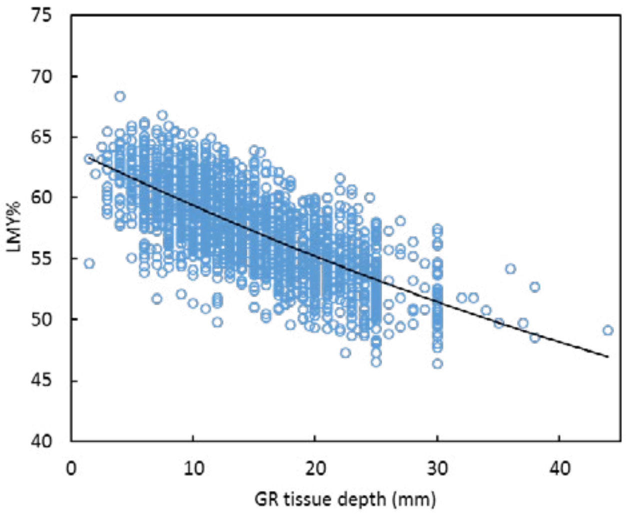
**Figure 23.** The relationship between SMY & LMY% (adapted from Hocking Edwards, Smith, Gardner, Pethick and Ball 2016).



### Low LMY% is due mainly to fat

Low carcase LMY% is due primarily to high levels of fat in lamb carcases. Although the accuracy of GR tissue depth measurement to estimate LMY% is low, there is a relationship between the two. This relationship demonstrates the importance of fat in determining LMY%. For carcases from the Sheep CRC INF, the LMY% ranged from 50% to 59% over the GR range of 30mm to 8mm (Figure 24).

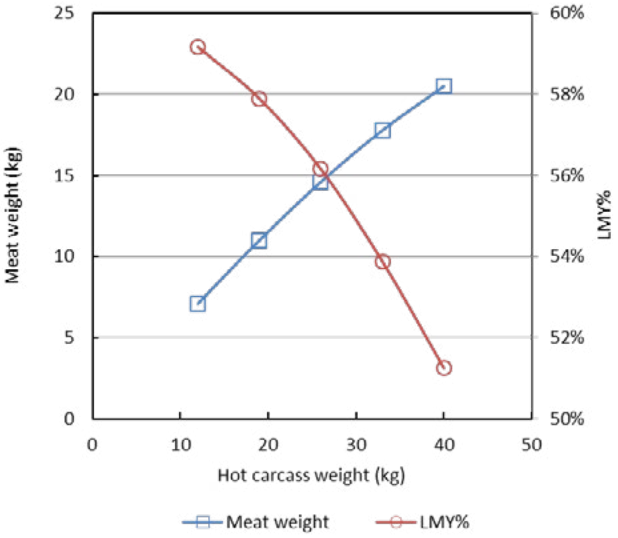
**Figure 24.** The relationship between GR tissue depth measured using a GR knife and carcase LMY% measured using a CT scanner (CT Lean%) (data from Sheep CRC Information Nucleus Flock). The solid black line represents the mean of all values and the blue dots represent values for individual lambs.



### LMY% decreases as carcase weight increase

Large carcases contain a greater quantity of meat than small carcases due to size alone. However, LMY% tends to reduce as hot standard carcase weight (HSCW) increases (Figure 25). Therefore, a payment system based on HSCW alone will not discriminate between low and high LMY% and may in fact reward carcases with lower LMY%.

**Figure 25.** The effect of hot standard carcase weight (HSCW) on the weight of meat in the carcase and the yield measured using a CT scanner (data from Sheep CRC Information Nucleus Flock).



## Muscle weights increase with increasing yield

Carcases from lambs bred in the Sheep CRC INF were deboned and the individual cuts weighed and measured. For an average carcase weight, the predicted weight of the loin ranged from 273gm to 440gm for LMY% of 45% and 70% respectively (Figure 26). Similarly, the eye muscle area ranged from 11.8cm$^2$ to 17.5cm$^2$ (Figure 27).

The round weight also increased with LMY% (Figure 28). However, it should be noted that there was considerable variation around the mean value, so while the mean value can be expected to be higher for high yielding carcases, this will not be true for every carcase due to biological variation.

**Figure 26.** **The loin weight for a carcase of 23kg for the range in LMY% from 45% to 70%. The red line is the predicted average value for the loin weight. The grey dots are the actual values for individual lambs to demonstrate the amount of variation in the data around the mean values.**

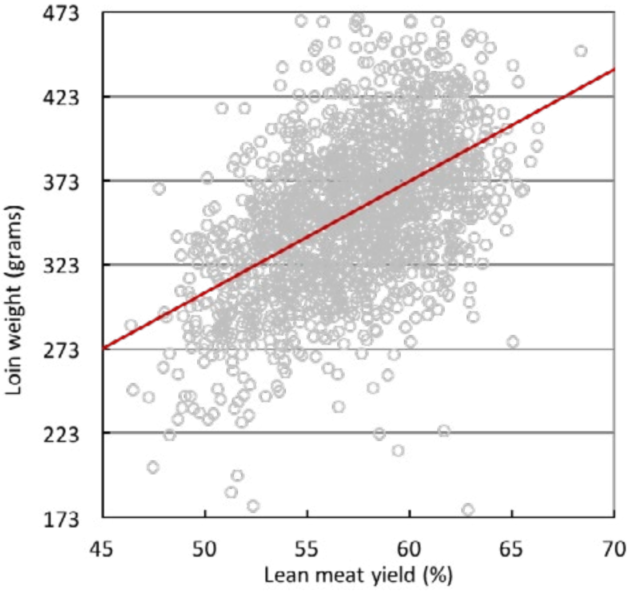


**Figure 27.** **The eye muscle area for a carcase of 23kg for the range in lean meat yield from 45% to 70%. The red line is the predicted average value for the eye muscle area. The grey dots are the actual values for individual lambs to demonstrate the amount of variation in the data around the mean values.**

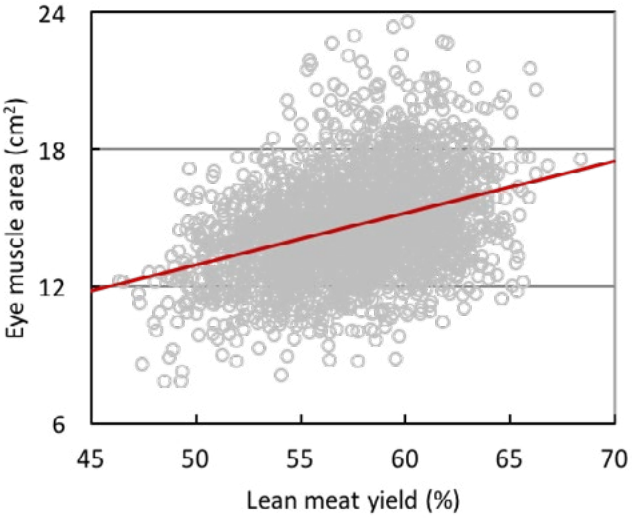
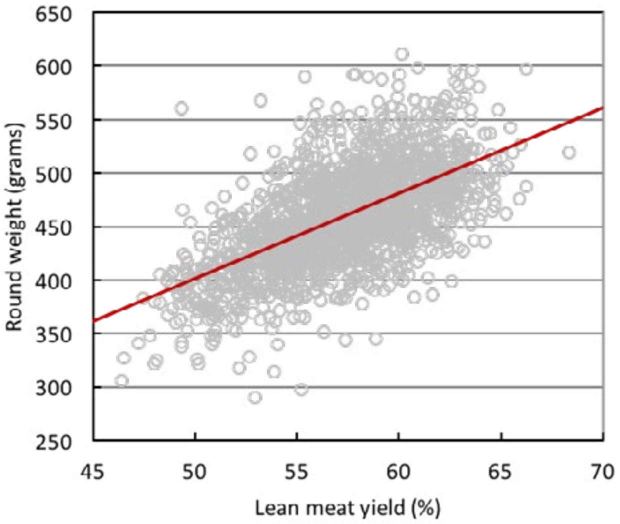


**Figure 28.** **The weight of the round (grams) for a carcase of 23kg for the range in lean meat yield from 45% to 70%. The red line is the predicted average value for the eye muscle area. The grey dots are the actual values for individual lambs to demonstrate the amount of variation in the data around the mean values.**



## Eating quality and LMY% are related

Eating quality tends to reduce with increasing LMY% for several reasons, including:

1. The meat from fast growing animals tends to have a higher proportion of fast twitch fibre types that are more susceptible to the effects of stress causing high pH.
2. Very lean animals can cool more rapidly and be more susceptible to cold shortening during the cooling process after slaughter. When this occurs, the meat will be less tender. Electrical stimulation can reduce the variation in tenderness due to cold shortening. Susceptibility to cold shortening is a reason why processors penalise lambs that score 1 for fatness.
3. High yielding animals tend to mature later and as a result, have lower levels of intra muscular fat (IMF) at the time of slaughter. As the IMF% reduces, consumers rate all eating quality attributes (tenderness, liking of flavour, juiciness and overall liking) of lamb meat lower (Figure 29).

The impact of IMF% on eating quality changes with LMY% (Figure 30). Increasing carcase LMY% reduced the eating quality (MQ score) by only 8 consumer points when IMF% was high (7%). However, the eating quality reduced by 27 points, falling below the acceptable benchmark of 50, when IMF was low (3%).

The MQ score is a weighted aggregation of the scores for tenderness, juiciness and flavour. This shows the importance of maintaining a high IMF% in higher yielding animals to maintain eating quality.

**Figure 29.** The association between consumer sensory scores for tenderness, flavour, juiciness and overall liking across the intramuscular fat range of 2.5% to 7% (Data courtesy of Sheep CRC).

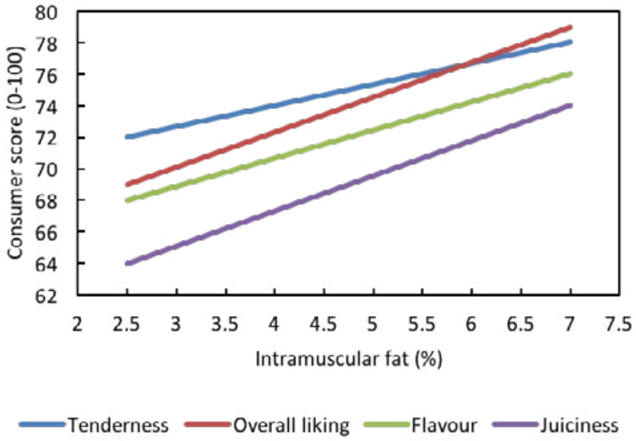
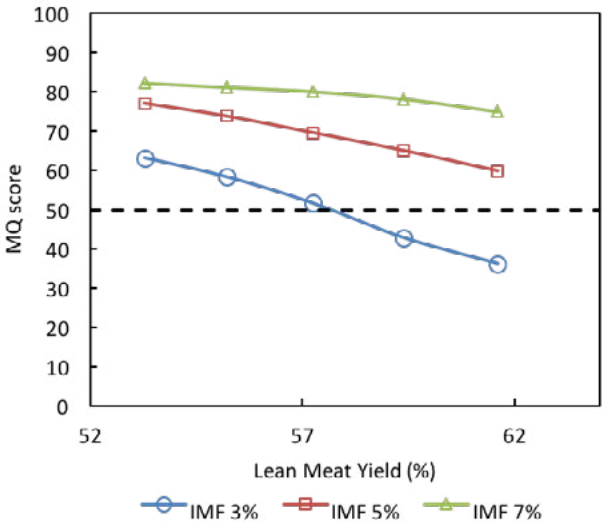


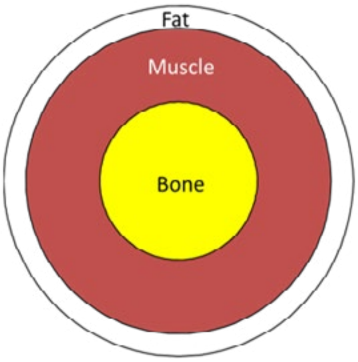
**Figure 30.** The relationship between LMY% and eating quality for high (7%), medium (5%) and low (3%) levels of intramuscular fat (IMF).



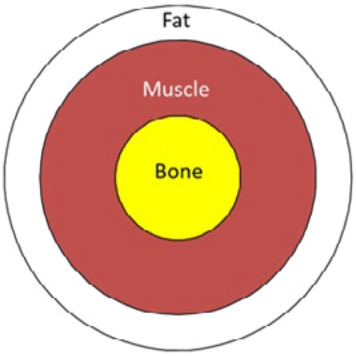
## Yield varies between primal cuts

Yield varies between the forequarter, saddle and hindquarter, with the hindquarter being the highest yielding and the saddle the lowest yielding (Figure 31). The hindquarter has the greatest muscle content, the forequarter the greatest bone content and the saddle region the greatest fat content.

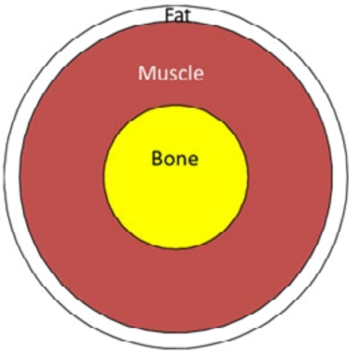
**Figure 31.** The average bone, muscle and fat percentage in the forequarter, saddle and hindquarter of lamb carcases from the Sheep CRC Information Nucleus Flock.



**Forequarter**
Bone 20%
Fat 24%
Meat 56%



**Saddle**
Bone 13%
Fat 37%
Meat 50%



**Hindquarter**
Bone 18%
Fat 17%
Meat 65%

## Practical steps

### Carcase fabrication

Carcase fabrication can be done centrally at the same site as the slaughtering process when the retail outlet is part of an integrated value chain. Or it can be done in a more traditional way at a separate retail venue, as is the case with butcher outlets trading independently of the slaughter plant.

Although the logistics and scale are quite different, the decisions made to optimise the value of a carcase will be similar, regardless of where and how the process occurs.

MLA and Sheep CRC have developed three decision tools to assist with cut fabrication. These are:

1. Lamb Value Calculator
2. Carcase Optimisation Tool
3. Butcher Calc

### Lamb Value Calculator

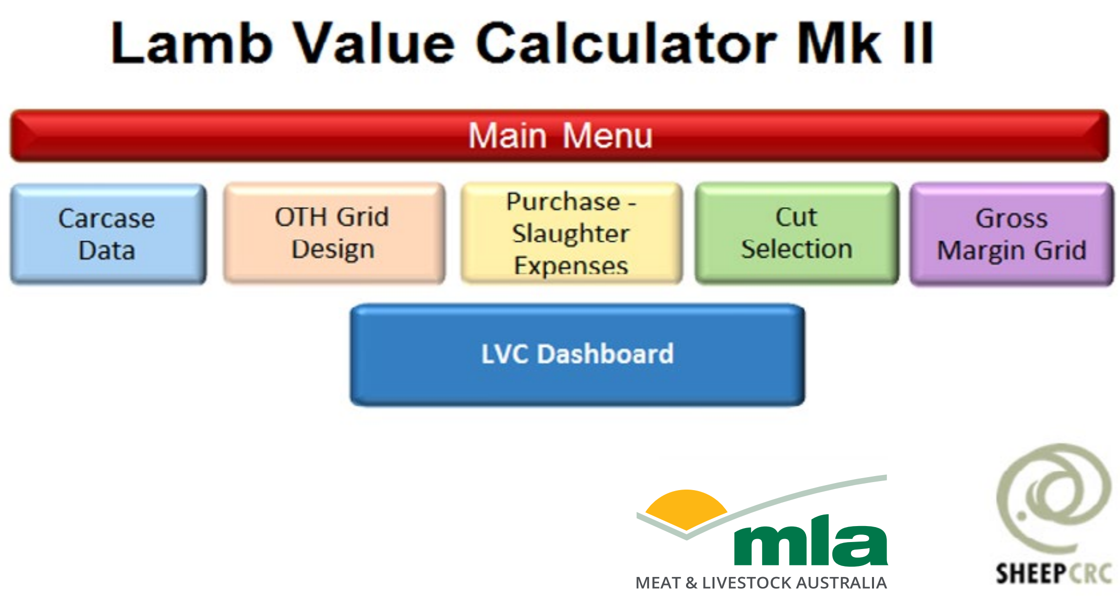
The Lamb Value Calculator is a spreadsheet model suited for use by a range of people, including retail butchers and boning room managers. Basic spreadsheet skills are required to run the calculator. The calculator requires some inputs from the operator including: cost of production, purchasing method, carcase specifications and cut selection.

Outputs are generated according to the inputs and include:

- Estimate of the retail value of a lamb carcase based on the particular specification
- Description of the composition of the carcase based on the hot standard carcase weight (HSCW) and LMY% estimates (GR fat depth or DEXA)
- Estimate the retail value and gross margin (GM) of each primal region and individual cut
- Assessment of the cost incurred along the supply chain
- Over the hook (OTH) price grid

By changing an input, a user can compare actual and target GM at a cut level. Figure 32 shows the dashboard of the Lamb Value Calculator. This is the starting point from which different menu options can be selected.

**Figure 32.** The dashboard of the Lamb Value Calculator tool.



## Carcase Optimisation Tool

The Carcase Optimisation Tool can assist with decisions before the deboning process. Essentially this tool can be used to optimise the value of a carcase by determining the:

- Best way to cut a specific carcase. The tool uses outputs from the Lamb Value Calculator to determine which of the options will yield the greatest profit.
- Best way to group carcases for cutting. Changing the cutting pattern in a production line comes at a loss of time and this represents a cost. Grouping carcases according to the best cutting specification maximises the efficiency of the boning process.

The Carcase Optimisation Tool is currently undergoing field testing.

## Butcher calc

This is a version of the Lamb Value Calculator modified for independent butchers to use in butcher shops.

## Monitor eating quality

Eating quality will remain a more difficult attribute to monitor at the retail end of the supply chain until some automated methods become available at abattoirs. Sourcing carcases from MSA accredited abattoirs will assist. The pathway from farm to slaughter will also ensure processing has been consistent with eating quality standards. This includes reducing the likelihood of cold shortening and optimising the rate of aging post slaughter.

In the future, technologies should be available to automate the measurement of factors such as pH and IMF to determine eating quality. Once available, monitoring these values will assist in balancing LMY% and eating quality for a particular carcase. Further reading on MSA sheep meat can be found at https://www.mla.com.au/Marketing-beef-and-lamb/Meat-Standards-Australia/MSA-sheepmeat.

## How does LMY% relate to MSA

The MSA system is a grading program designed to guarantee the eating experience for consumers of Australian lamb and sheep meat. Currently, it works on a pathway system where lambs graded MSA have been managed in a way that is consistent with good eating quality. The plan in the future is to be able to further differentiate premium carcases by measuring a range of carcase attributes on the slaughter floor or during processing (e.g. eating quality factors such as IMF, animal age and fatness, but also LMY%).

This capability will depend on the successful development and commercialisation of advanced measurement technologies being undertaken by the ALMtech research project. The MSA system will then predict the eating quality and grade a sheep carcase accordingly. Given LMY% negatively influences eating quality, being able to measure eating quality and LMY% together will be an important step forward.

# Conclusions

This guide has been designed primarily to describe LMY% and to explore the opportunities that exist to improve LMY% and use LMY% information across the lamb meat supply chain.

Work undertaken by the Sheep CRC, ALMTech, MLA and collaborating seedstock producers provides a sound scientific basis for the information presented and ensures the information is both relevant and practical for the Australian industry.

A key finding is the inextricable link between LMY% and eating quality. The essential rule to achieve a favourable outcome is to realise one component cannot be considered without the other at any point in the supply chain.

New methods to measure LMY% precisely and accurately are rapidly making their way into commercial applications. These are being supported by development of systems and technologies that will automate processing and information flow along the supply chain.

Understanding LMY% will be essential for all members of the lamb meat supply chain as new technologies to measure lamb carcase LMY% and optimise this information become available.

**Table 8.** Summary of key value propositions for each phase of the lamb meat supply chain.

| Application | Activity | Value proposition |
|---|---|---|
| **Lamb production** | Make | Produce lambs high for both LMY% and eating quality to achieve feed efficiency on farm and compliance with carcase grid specifications |
| **Path to market** | Manage | Choose the path with the shortest practical time from farm to slaughter for the highest carcase weight and best eating quality |
| **Slaughter** | Measure | Measure carcases to provide feedback to farmers and make strategic processing decisions |
| **Retail** | Manufacture | Optimise cut fabrication for processing efficiency and to satisfy customer requirements for value and eating quality |

# Acronyms

| Acronym | Phrase |
|---|---|
| **ALMtech** | Advanced livestock measurement technologies project |
| **ASBV** | Australian Sheep Breeding Value |
| **CL** | Chemical lean |
| **CT** | Computed tomography |
| **DEXA** | Dual Energy X-ray Absorptiometry |
| **DP** | Dressing percentage |
| **EQ** | Eating quality |
| **Estim** | Electrical stimulation |
| **FCE** | Feed conversion efficiency |
| **GM** | Gross margin |
| **GR** | Site for measuring lamb carcase fatness |
| **HSCW** | Hot Standard Carcase Weight |
| **IMF** | Intramuscular fat |
| **INF** | Information Nucleus Flock (now the MLA Genetics Resource Flock) |
| **LDL** | Livestock Data Link |
| **LMY%** | Lean meat yield |
| **LVC** | Lamb value calculator |
| **MQ score** | Meat quality score |
| **MLA** | Meat & Livestock Australia |
| **MSA** | Meat Standards Australia |
| **NIR** | Near infrared spectroscopy |
| **PEMD** | Post weaning eye muscle depth (ASBV) |
| **PFAT** | Post weaning fat depth (ASBV) |
| **PWT** | Post weaning weight (ASBV) |
| **SF5** | Shear force |
| **SMY** | Saleable meat yield |
| **SNP** | Single nucleotide polymorphism |
| **VIA** | Video Image Analysis |
| **Sheep CRC** | Cooperative Research Centre for Sheep Industry Innovation |

# Further reading

- Sheep meat eating quality

Improving lamb and sheep meat eating quality – A technical guide for the Australian sheep meat supply chain. (Young, Pethick & Ross 2005) MLA.

- Livestock Data Link (LDL)
  - https://www.mla.com.au/research-and-development/livestock-data-link/
- Sheep assessment manual
  - published by the MLA Market Information Services (2017)
  - https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/minlrs-information-brochures-etc/mla_sheep-assessment-manual_jan-2017.pdf
- Sheep genetics
  - Sheep genetics website http://www.sheepgenetics.org.au
  - LAMBPLAN Terminal Eating Quality Indexes Eating Quality (EQ)
  - LAMBPLAN Terminal Eating Quality Indexes LAMB2020 + EQ (LEQ)
- MSA sheep meat
  - https://www.mla.com.au/Marketing-beef-and-lamb/Meat-Standards-Australia/MSA-sheepmeat

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