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Improving lamb lean meat yield

A technical guide for the Australian lamb and sheep meat supply chain

SHEEP CRC

Australian Government
Department of Industry and Science
Business
Cooperative Research
Centres Programme

Improving Lamb Lean Meat Yield

A technical guide for the Australian lamb and sheep meat supply chain

This manual has been prepared and published jointly by the CRC for Sheep Industry Innovation and Meat & Livestock Australia.

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Executive Summary

Australia's sheep meat industry is at a critical juncture as producers and processors grapple with the genetics, economics and technology required to deliver the right percentage of lean meat yield (LMY%) from each carcase in order to satisfy consumer demands.

Lambs are normally sold on farm or in saleyards on a per head basis and/or direct to processors on carcase pricing grids using weight and fat tissue depth. These measures are poor predictors of final carcase LMY% and final customer value is not distributed along the value chain accurately. This results in unclear market signals to producers, with the price grids having no capacity to reflect end customer value.

The goal for industry is "value-based marketing"—a term that describes defining market specifications and price based on the individual merit of carcases and/or cuts.

Without this differentiation, no real incentives are given for producers to purchase "better" breeding stock, to finish animals to better meet slaughter endpoints or for processors/retailers to trim lamb and avoid selling excess fat down the chain, and for retailers and purveyors to purchase products differently than in the past.

When processors and retailers can access technology that is easily able to measure LMY%, they will be able to provide real time price signals to producers, who in turn will be able to adjust their genetic selection to better meet the market signals.

This technical guide sets out the current state of play for producers and processors in addressing this challenge, including the latest technology being tested to accurately measure LMY% at line speed in abattoirs, and the genetic tools available to producers to respond to market signals.

Introduction

This technical guide has been written as a reference for the lamb and sheep meat industry to explain lean meat yield percentage (Lean meat yield% or LMY%) and the factors that influence it.

It is for use by individuals and companies who seek further information on how to achieve optimum LMY% in lamb and sheep meat.

The technical manual is also useful for meat processors wishing to establish a premium payment system for higher yielding carcases and for farmers and extension officers wanting further information on how to produce lamb carcases with higher yields.

It provides information on the critical control points along the supply chain and a reference for establishing supplier and customer requirements for LMY%.

Various sections of the manual have been written with a focus on the requirements of different participants in the supply chain, however all industry participants are encouraged to read all chapters to gain an understanding of the issues faced.

Table 1. Chapter overview and description of detail

Chapter	Aimed at	Description
1. Overview	All participants in the supply chain	Define LMY%
2. Industry measures of LMY%	All participants in the supply chain	Understand the different assessment methods to determine LMY%
3. Economic importance of improving LMY% across supply chain	All participants in the supply chain	Understand the impact of LMY% on profitability across the supply chain and its importance to meat processing and farming businesses
4. The biology of factors affecting LMY%	Researchers	Identify and understand the key factors which influence LMY%
5. Producing high yielding carcases on farm	Farmers, livestock buyers and extension officers	Identify the effect of genetics and nutritional needs on animal performance and LMY%
6. Research findings and implications	Researchers and extension officers	Future trends and potential developments are identified
7. Conclusions	All participants in the supply chain	Summary of key messages

Chapter 1

Overview

Lean meat yield percentage is a key efficiency and profit driver throughout the lamb and sheep meat supply chain.

The financial value of a carcase is largely determined by the quantity of saleable meat, which is the weight of the muscle relative to the carcase. Producing higher yielding lambs for slaughter is beneficial to producers, processors, retailers and consumers and improves the efficiency of the lamb supply chain.

For processors, a high yielding animal represents increased efficiency in the boning room. These carcases require less labour to trim fat and there is less carcase wastage. The need to remove fat represents a significant processing cost, as does the loss of saleable product in lambs that are fatter and lower yielding. For this reason most processors offer price grids that take into account both carcase weight and fatness. Increased lean meat yield percent (LMY%) is closely associated with a higher saleable meat value.

For producers, higher yielding animals can be finished to heavier weights without becoming overly fat and accruing penalties. Additionally, fast growing, high yielding animals can be finished either faster or to heavier weights, in a shorter period of time, resulting in savings on feed costs to the producer.

For consumers, there is firstly a desire to purchase meat which is perceived to be healthy. Consumers have clearly indicated that excess fat on lambs is unacceptable. Over 90% of consumers trim lamb fat before or after cooking. Secondly, lamb is sold in lower yielding formats at a retail level (i.e. more bone and fat) compared to beef, pork and chicken and is typically more expensive, especially when compared on a $/kg basis of lean meat at retail. Consequently consumers want to purchase cuts of meat that display a high quantity of red meat with less bone and subcutaneous fat. This is most efficiently achieved by producing leaner, more muscular animals on farm for slaughter. Thirdly, consumer trends are demanding more retail ready lamb products which require larger, leaner carcases because they are often produced from single muscles or two muscle groups (Trim Lamb Topsides, Rounds, Rumps etc.) rather than multi–muscled cuts such as a traditional leg of lamb.

Importantly, producing carcases with higher LMY% becomes more significant as the product progresses to a butcher or to retail display as this end of the supply chain is where the point of maximum fabrication (the breaking down of a carcase into consumer cuts) occurs. A meat processor might do some boning e.g. bone the saddle region into a lamb rack or short loin area, but more often will sell the forequarter and legs with minimal processing. However, the retailer will typically fabricate some of the legs further e.g. rump steaks, round steaks and easy carve legs, and therefore a higher LMY% equates to an even higher amount of saleable meat product. Therefore, LMY% is very important all the way from paddock to plate. For integrated supply chains that go through to retail there is massive value to be gained in improving LMY%.

Currently the reward for increasing LMY% is poorly captured under the current grid system in Australia. Processors use carcase weight and a single point measure of fatness (Chapter 2) to reflect LMY%. This approach has a limited capacity to predict carcase LMY%, and almost no capacity to describe variation in the distribution of lean between regions of the carcase. In response to this the Australian lamb industry has been assessing and developing a number of different technologies to predict LMY% within abattoirs and these are discussed in Chapter 2.

The challenge for the lamb industry is to create an economic incentive for producers to select for yield to ensure that the potential gains in carcase value will be achieved across the wider industry. It is understood that some processors pay premiums to producers with "good lambs", indicating there is an appreciation for carcases with superior conformation. However, many processors still pay a flat price per carcase or on a carcase weight basis. It is increasingly important that price signals reflect not just more carcase weight as it may represent increasing amounts of fat. Therefore, unless processors understand the yield benefits available to them on a carcase basis, and have a cost effective means of measuring and reporting feedback, payment structures will continue to send the wrong market signals. Lean meat yield payment systems distribute value more equitably; more lean meat should receive a greater reward than less lean meat—a true value based marketing principle.

With continued evolution of the payment schemes for lamb there is the potential to improve profitability through the use of genetic selection for increased yield. Increasing selection pressure towards better genetics is already delivering increases in lean meat yield, productivity and real industry benefits. Meat and Livestock Australia (MLA), Sheep Genetics, Sheep CRC program and collaborating seed stock producers are making high quality genetic lines available to industry. It is now possible for producers of lambs to select for improvements in LMY% using newly generated Australian Sheep Breeding Values (ASBVs) for this trait (LMY%). The rate of improvement in carcase muscling in Australia and the uptake of genetic tools to improve muscling while reducing fat deposition indicates that improvement in carcase lean meat yield is occurring.

Lean meat yield defined

The technical definition of Lean Meat is skeletal muscle of the carcase with all visible subcutaneous and intermuscular fat removed. The terms Lean Meat and muscle are used interchangeably in the Australian sheep meat industry.

Meat yield means different things to different sectors of the meat industry. Researchers often talk about the yield of dissectible muscle (usually referred to as lean meat percentage or LMY%). On the other hand, suppliers of carcase meat to the domestic and export markets are most interested in the yield of saleable meat (including bone and fat in some cuts) from each carcase. Exporters of bulk-packed meat for manufacturing specify the percentage of chemical lean (CL). This is the amount of lean red meat compared to the amount of fat in a sample of meat as determined by one of a number of approved methods of sampling, testing and analysis. Due to the variety of interpretations, there continues to be confusion regarding the definition of yield. For the purposes of this manual, we will work with the following definitions.

Lean Meat Yield (LMY) is a standard measurement, against which any lamb may be compared. The LMY of a carcase decreases as the amount of carcase fat increases but increases if the muscle to bone ratio is increased. LMY does not change from works to works and it is not dependent on the production specifications such as trim differences that a carcase may be broken/boned out to.

Lean Meat Yield (kg): The weight of lean meat which is recovered after the separation of all muscle tissue from the fat and bone components of a carcase using basic commercial techniques. All bone and salvage fat is therefore removed.

Lean Meat Yield Percentage (LMY%): Is the Lean Meat Yield (kg) expressed as a percentage of the initial Hot Standard Carcase Weight. All bone and salvage fat is removed.

Saleable Meat Yield (kgs): Is the weight of saleable meat product produced from a carcase, to a set of specifications. Saleable Meat Yield is variable and dependent upon the specifications which are being used to fabricate the saleable cuts – particularly with respect to the fat trimming level and level of bone inclusion. These cutting specifications vary between individual product lines within boning rooms and between individual companies.

Computed Tomography Lean Percentage (CT Lean %): is the weight of lean meat within a carcase measured using a computed tomography scanner and expressed as a proportion of the carcase weight. This is not measured commercially, however lean meat yield prediction tools adopted by industry will be calibrated against this measurement.

Dressing Percentage: Is the weight of a dressed carcase expressed as a percentage of the live weight of the animal from which it was processed. This is not yield. Dressing percentage is useful for the pre-slaughter estimation of carcase weight. Through the analysis of feedback, producers will get to know and understand the “dressing percentage” of their own animals.

Chemical Lean Percentage (CL): Chemical lean is defined as the amount of lean red meat compared to the amount of fat in a sample of meat, using an approved method of sampling and testing. The chemical lean of a box of trim for example is included in the trade description as a minimum percentage e.g. 75CL, is where 75% of the box will be lean red meat and 25% will be fat. Tolerances can be applied where the sample accuracy and confidence limits have been determined statistically.

Chapter 2

Industry measurement of lean meat yield%

Reliable measures of LMY% are needed to provide feedback and price signals along the supply chain. Ultimately farmers need to be able to assess how their animals are performing and adjust their genetic selection and management practices accordingly. Unfortunately LMY% is not a parameter that can be easily measured in a commercial environment. Processors of all livestock species are searching for more accurate and time efficient measures to determine carcase value.

This section will discuss various indicators of LMY% in both the live animal and carcase.

Current measures

The Australian lamb and sheep meat industry relies largely on hot carcase weight and GR tissue depth to describe LMY%. The GR site is 110mm from the carcase/live animal midline from the spine over the 12th rib and represents the total depth of tissue at this point (Figure 1). This site is used as a reference point because it is easy to measure on the hot carcase and provides a good indication of the overall fatness of the whole carcase. It is important to note that higher muscling lambs will have higher muscle and fat at the GR site. GR tissue depth is either assessed using manual palpation or objectively using a GR knife. These aspects of carcase grading are discussed below along with the Video Image Analysis technique.

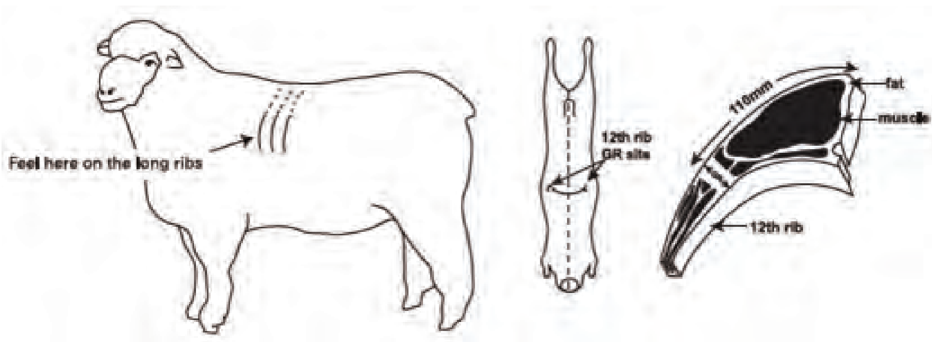


Figure 1. Locating the GR site on both the live animal and the carcase

Table 2 compares methods of predicting LMY%. The accuracy is determined by both the measurements and carcase weight. In the past, technologies were 'trained' or calibrated using bone-out data generated by professional butchers, however in recent years the use of Computed Tomography (CTscan) for benchmarking has increased in Australia.

Table 2. Current Methods of Determining LMY% and Accuracy of Predication

(Data courtesy of Sheep CRC)

Prediction Method	Accuracy*	Most suited to, and location	Limitations
Hot Standard Carcase Weight (HSCW)	12%	Measure on hot carcases, end of chain	
HSCW plus Palpated Fat Score (AUSmeat accredited operators)	20%	Measure on hot carcases, end of chain	Higher operator error (especially at fast speed)
HSCW plus GR Knife Fat Score (measured fat scores)	30%	Slower chain speeds, end of the chain	Fast chain speed
HSCW plus GR Knife (mm) (measured with ruler)	35%	Slower chain speeds, end of the chain	Fast chain speed
HSCW plus AUSmeat Sheep Probe Blade driven through GR tissue until it strikes the rib	34.6%**	Measure on hot bodies and slower chain speeds, end of the chain	Operator error and no longer commercially supported
Video Image Analysis HSCW, carcase dimensions and light reflectance measured	47%	Operates with modern kill chains, no human error	Ageing technology, not calibrated to estimate fat score/depth

** Accuracy of yield prediction technologies based on their ability to predict CT lean%.*
***AUSmeat Sheep Probe predicted GR depth (mm) measured by ruler with 99% accuracy*
Fat Score: A simple scoring system where fat scores vary from 1 (leanest) to 5 (fattest)

GR Knife Fat Score: Use of GR Knife to determine fat score, corresponds to GR depths measured in 5 mm graduations
GR (mm): GR tissue depth measured by ruler or GR knife in millimetre increments

Carcase Weight

Carcase weight contributes to Lean Meat Yield (kg) by increasing the overall weight of the muscle and carcase. Liveweight and dressing percentage can be used to estimate carcase weight using lamb weighing scales and guidelines for dressing percentage determination.
Figure 2 shows a strong positive relationship between hot standard carcase weight (HSCW) and LMY (Kg) however it can be seen from Figure 3 that there is a strong negative relationship between HSCW and LMY%. Therefore trading on HSCW alone ignores this relationship and may reward lower LMY%.

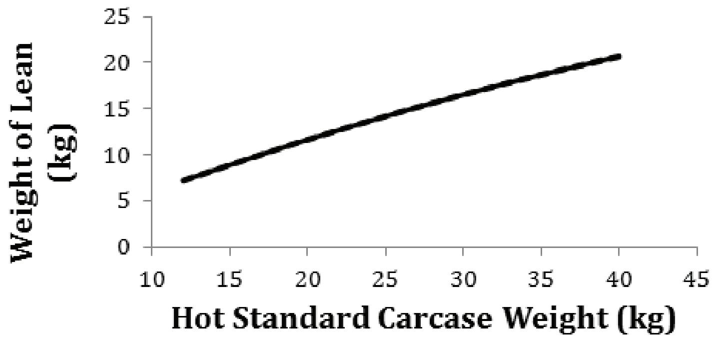


Figure 2. The effect of hot standard carcase weight (HSCW) on the weight of lean in the carcase measured using a CT scanner

(Data courtesy of Sheep CRC)

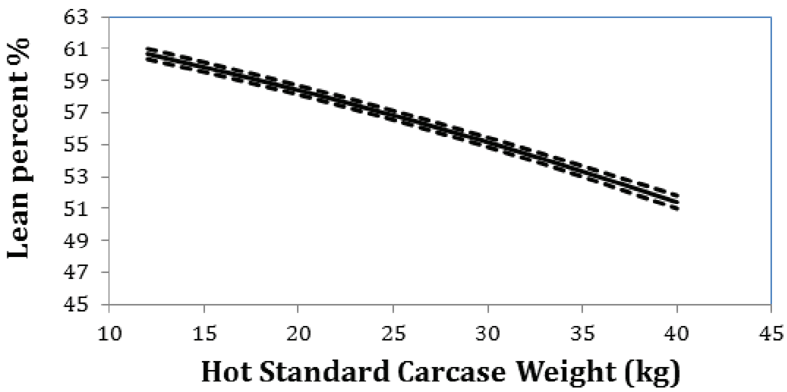


Figure 3. The effect of hot standard carcase weight (HSCW) on percent lean in the carcase measured using a CT scanner

(Data courtesy of Sheep CRC)

Fat and tissue depth

1. *Manual assessment of GR tissue depth—fat score*

To determine fat class, AUSmeat accredited/calibrated operators palpate the GR site (11cm from mid-line over the 12th rib) using their fingertips to arrive at a prediction of fat score. The AUSmeat fat classing system is a simple (1–5) scoring system used to estimate the amount of fat cover on both the live lamb and carcase. Fat scores vary from 1 (leanest) to 5 (fattest). Scores are based upon the tissue thickness (both fat and lean tissue) at the GR site and correspond to GR tissue depths measured in 5mm graduations.

2. *Objective assessment of GR Tissue Depth*

The GR tissue depth is determined objectively by a cut and measure technique using a GR knife or an AusMeat probe at the GR site (Figure 4).

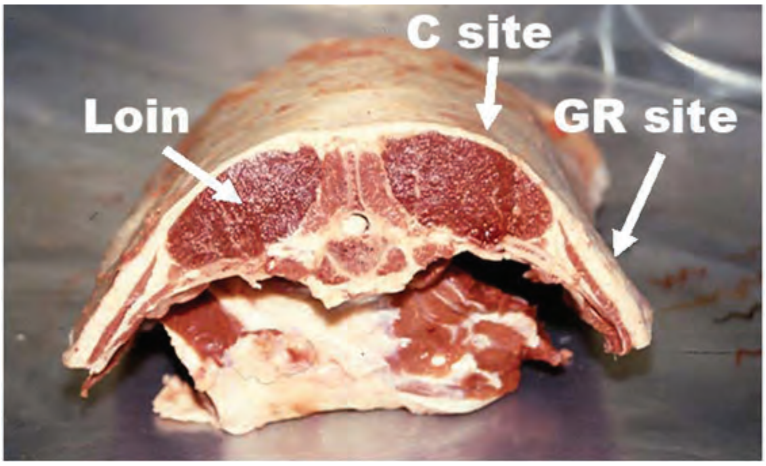


Figure 4. Location of GR site and C site on lamb loin cut through at 12th rib

While grading carcases on the basis of GR tissue depth is an industry standard, the way in which this is measured is not. AUSmeat, however, runs an accreditation course to ensure operators are predicting within a tolerance range.

The GR Knife is a simple device that is a combination of a ruler and knife (Figure 5). Although this is an improvement on the prediction using manual palpation, this measurement is 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. The GR knife is a good and pragmatic measure but not the latest technology. There is a strong negative correlation between GR tissue depth measured using a GR knife and LMY% (Figure 6).

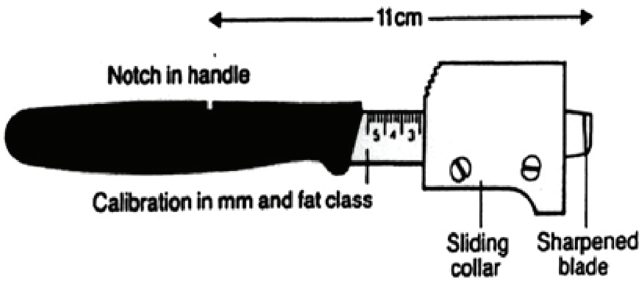


Figure 5. GR knife for use measuring GR tissue depth

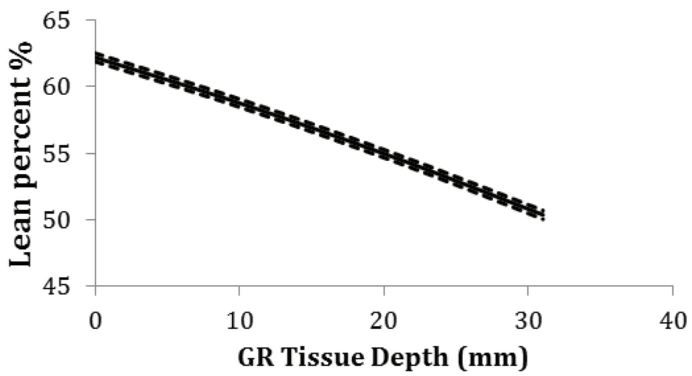


Figure 6. The effect of GR tissue depth measured using a GR knife on percent lean in the carcase measured using a CT scanner

(Data courtesy of Sheep CRC)

AUSmeat Sheep Probe—This device was designed to capture tissue depth at the GR site using a blade that is driven through the tissue until it strikes the rib below. This unit is prone to operator error but less so when measured on hot carcases before the fat has "set" (as it uses a compression plate which is placed against the carcase to minimise point compression at the GR site), can only be taken after skin removal, usually at the end of the chain, and may be limited to slower chain speeds (depending on the number of operators). Note that this device is currently not supported by any commercial company.

Table 3 shows the relationship between fat score and GR tissue depth, along with what should be felt by the operator at the 12th long rib.

Table 3. Fat score, GR tissue depth and feel over long ribs during fat scoring

Fat Score	1	2	3	4	5
GR tissue depth using GR knife in mm	0 to 5 mm	6 to 10 mm	11 to 15 mm	16 to 20 mm	20 mm and over
Feel at the 12th long rib	Individual ribs can be felt easily. Cannot feel any tissue over the ribs.	Individual ribs easily felt but some tissue present.	Individual ribs can still be felt. Can feel more tissue over the rib.	Can only just feel ribs. There is fluid movement of tissue.	Ribs cannot be felt. Tissue movement very fluid.

Measuring LMY% with Video Image Analysis

Video Image Analysis (VIA) enables processors to estimate LMY% and distribution with sufficient accuracy to allow reliable feedback to producers (Figure 7). Brand names of VIA currently being used commercially include E+V (www.eplusv.de), VIAscan® (www.cedarcc.com), the Lamb Vision System (www.rmsusa.com), and the Carometec BCC system for beef. Many VIA units are used in the European beef industry especially to assess carcases according to the European EUROP grid carcase classification system.

VIA is a non-intrusive station on the slaughter floor that operates automatically and assesses many attributes of a 'hot' dressed carcase as it passes along the slaughter chain. The advantage of this system is that it is not subject to human operator error and that it can keep pace with modern kill-chains.

VIA systems consists of a booth, an artificial light, a high quality digital camera and a computer program that analyses the images and extracts carcase measurements. These measurements provide a prediction of yield down to a primal basis. The system does not require an operator; its operation is supervised by the operator at the Grading Station.

The outputs from the VIA are customisable according to requirements such as primal weight predictions, chemical lean composition, and size and conformation measurements. The results of analysis can directly drive carcase marking, cutting or sorting and can be exported to on-floor systems and data management systems.

A series of algorithms underpin the calculations performed by a VIA system. For the Australian system VIAscan® (seen in Figure 7), the algorithms are based on a series of cutting trials (two cross bred and one Merino), which included a wide representation of breeds, crosses and gender. Being an indirect measure, it needs regular calibration especially as lamb genetics change—an extreme case as one moves a VIA data set to a new country with new genetics and weights. The VIAscan® has also been benchmarked (although not "trained") against CT lean.

Figure 7. VIAscan® technology
(Photo courtesy of WAMMCO)

Future methods of LMY% evaluated

The Australian lamb industry has been assessing and developing a number of different high-throughput technologies to predict LMY% within abattoirs with a number of commercial partners. This activity is being driven at two levels, the first targeting simpler and less expensive devices that will deliver single-site measurements of tissue depth. These devices predict LMY% with less precision (R^2 range from 0.2–0.4), and at the whole carcase level only. They include mechanical tissue depth probes, ultrasound, and boning room vision systems that can estimate tissue depth at the GR site, or muscle and fat depth at the C-site (5cm from the mid-line over the 12th rib) or estimate LMY% based on carcase colour and shape. Secondly, there are more expensive whole carcase systems that will enable more accurate determination of LMY% (R^2 range from 0.4–0.7) as well as determining lean distribution between different regions of the carcase. These include carcase vision systems, dual energy x-ray absorptiometry (DEXA), and computer aided tomography scanning (CTscan).

In all cases these LMY% prediction devices are trained upon a central "gold-standard" dataset which is generated using CTscans of carcases scanned in 3 sections (fore, saddle and hind) to generate CT Lean%. CTscan is the most accurate way of determining the proportions of fat, muscle and bone within a carcase. This central CTscan dataset has the advantage of generating consistent and repeatable data, not subject to human bias. Thus processors can select a LMY% prediction technology that best optimises their trade-off between cost, speed, and precision.

It is imperative that new technologies for carcase grading:

1. Can operate at commercial chain speeds (up to 12 lambs/minute);
2. Are non-invasive for the carcase i.e. don't damage the carcase;
3. Are precise and repeatable in their prediction of LMY%;
4. Are robust for use on a slaughter chain;
5. Are commercialised by a reputable company with excellent backup and service.

Hyperspectral Imaging

High-resolution camera imaging (Hyperspectral imaging or HSI) is being investigated for determining fat depth, eye muscle depth and area, and intramuscular fat and meat colour in split carcases. A cut loin surface is essential for this technology. This type of system would be employed at the point of carcase splitting and hence may provide information to underpin bone-out decisions further down the line. Prototype HSI cameras began testing in early 2015 (Figure 8).

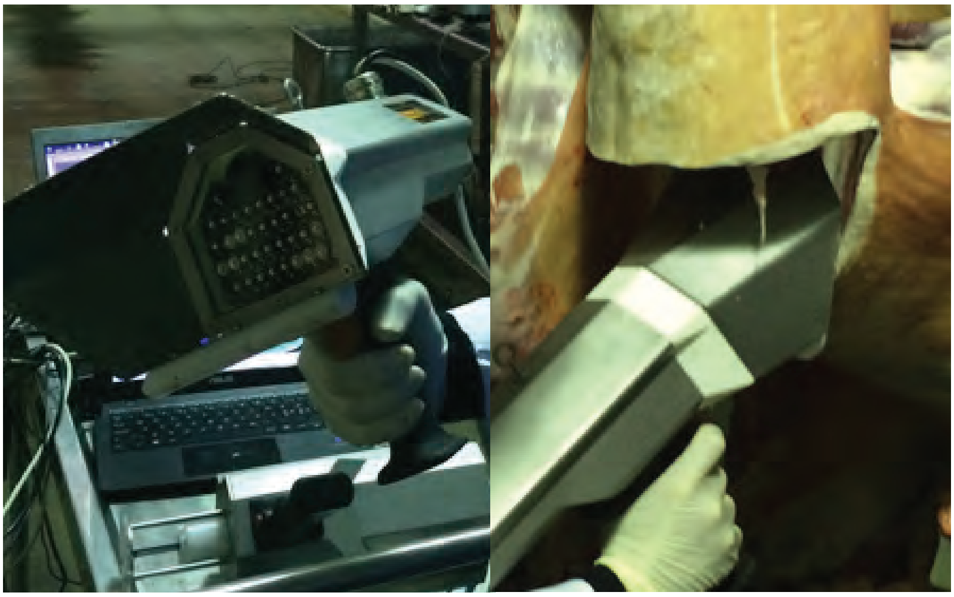


Figure 8. Prototype Hyperspectral imaging (HSI) camera

(Photo courtesy of Carometec)

This system, which takes a picture(s) of the loin surface after carcase splitting, shows good research potential for its validity in lamb and pork. The high resolution allows precise delineation of muscle, fat and bone, which will allow an accurate prediction of lean meat and primal yield but also offer the possibility of estimating meat colour and Intramuscular Fat (IMF). It would offer the first example of a system for measuring yield and meat quality together in lamb. Furthermore it would allow accurate sizing and sorting of rack primals for different market segments.

HSI works like other spectral imaging techniques by collecting and processing information from across the electromagnetic spectrum. Traditional imaging technology (such as VIA systems) provides a high spatial resolution but with limited spectral information, hence, it may not be useful for detecting minor features in a sample. Meanwhile, spectroscopy alone provides high spectral resolution over both visible and near-infrared spectral regions but with virtually no spatial information.

Due to the combined features of imaging and spectroscopy, HSI not only provides information on extrinsic characteristics of the product (i.e. shape, size, appearance and colour) through image feature extraction, but it can also help in identifying the properties or chemical constituents of the product through spectral analysis.

To judge the overall quality of meat products for classification and grading tasks, multiple extrinsic and intrinsic factors are often needed. HSI could be an effective technique to grade meat based on both extrinsic properties, such as appearance (size, intramuscular fat, colour), and intrinsic properties (maturity or tenderness), which are all important in determining the overall quality of meat. The non-destructive nature of HSI is an attractive characteristic for applications on raw materials.

GR impedance probe

The GR impedance probe-type device (Figure 9) is a modification of the commercially available Fat-o-Meat’er I and II described later in the Chapter. The probe incorporates electrical impedance (or current) technology and has the potential to measure Intramuscular fat (IMF) and GR depth. The basis of electrical impedance technology is the difference in electrical conductivity between muscle and fat tissue with fat having 10 times more impedance than muscle. The higher the amount of IMF, the greater the impedance of the current through muscle of the carcase. Impedance has been demonstrated to be an accurate predictor of fat-free muscle mass in live pigs and their carcases.

Previous experimental models of the GR Impedance probe involved a row of needles being inserted into the loin muscle and small electrical currents being conducted between the ends of each needle. However this probe model was not successful in measuring IMF nor GR depth. A second probe is currently being considered with additional collaboration from the Danish Meat Research Institute and this will have a circular conformation of pins. Research will be conducted in 2016 to determine if this technology is worth pursing in lambs.

Figure 9. Carometec GR-Impedance probe

(Photo courtesy of Carometec)

2D X-ray Scanning

Two-dimensional (2D) X-ray images are being used commercially to direct robotic cutting devices. The potential to use the pixel densities from these 2D X-ray images to calculate LMY% has been assessed, however the pixel contrast provided no capacity to determine lean meat yield (%). Pixel values tended to reflect the depth of tissue that the X-rays were passing through, as opposed to the tissue composition. Therefore this technology cannot obtain a reliable determination of bone, muscle, and fat so has not been pursued for measuring LMY%.

Combining 2D X-ray with Dual Energy (DEXA)

This work stems from the original testing of the 2D X-ray work (described above). This imaging system has been adapted to enable the capture of Dual Energy (DEXA) images capable of determining carcase composition. Early testing of an on-line DEXA system yielded positive results, and therefore a prototype system has been installed at one Australian abattoir and is currently being calibrated to measure Australian lamb. It has the potential to scan up to 30 carcases per minute – well beyond the fastest chain speed of any Australian lamb abattoir.

Computer tomography (CT) scanning

Computed tomography (CT) scanning offers the most accurate way of determining the proportions of fat, muscle and bone within a carcase and live animal. CT is a medical imaging technique that produces images of body cross-sections, using low dose X-rays, without resulting in any destruction of the carcase. These detailed images allow a very accurate estimation of body composition and tissue distribution. 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 (Figure 10), or more comprehensively from multiple adjacent scans extending the entire length of the body. Very recent research in pork by the Danish Meat Research Institute suggests line speed CT scanning could be a commercial reality in the future (Figure 11).

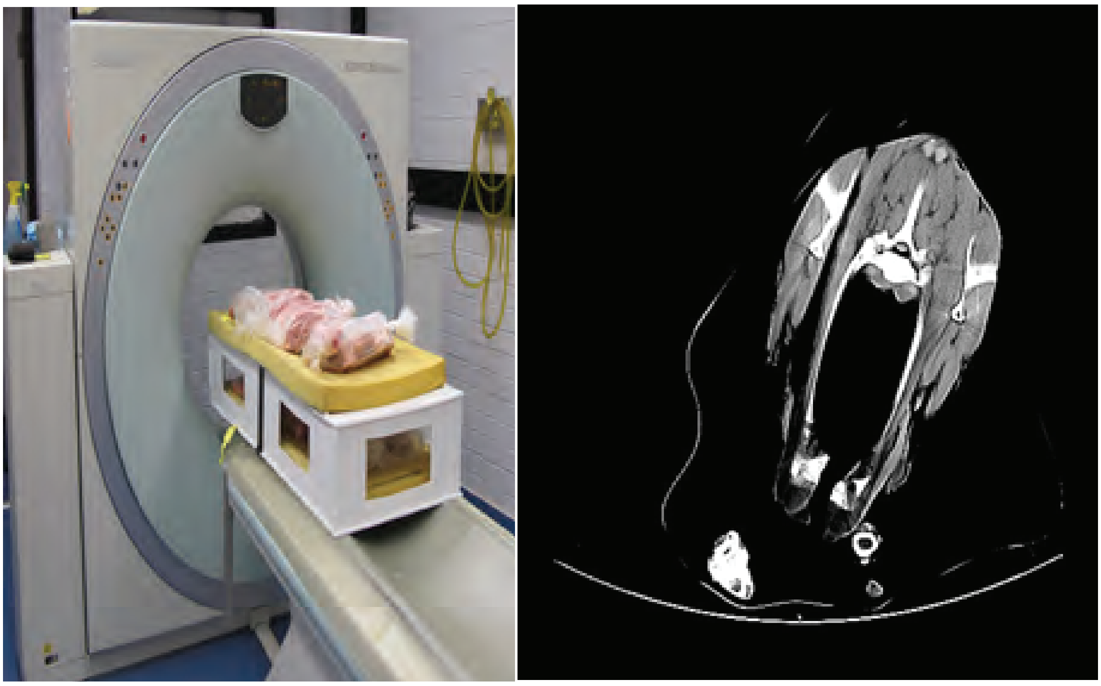


Figure 10. Lamb carcases being CT scanned and resultant image

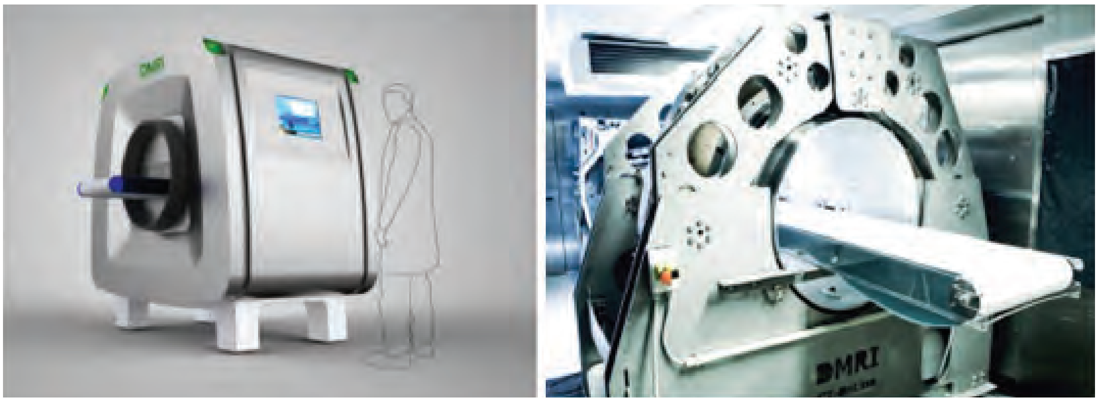


Figure 11. Danish Meat Research Institute (DMRI) CT machine of the future (left) and a research CT unit (right)

(Photo courtesy of DMRI)

The wider use of performance recording and selective breeding in sheep, together with the use of new technologies such as CT scanning, could assist genetics programs in the future to increase the proportion of lambs meeting fat and conformation grades. Although not used commercially in live sheep, CT can measure the total muscle, fat and bone proportions in a sheep. 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.

Lower accuracy methods used for LMY% prediction

A range of devices have been assessed by the Sheep CRC, in many cases on the basis of their capacity to capture tissue depths at key points within the carcase. At this stage none of the following devices are considered accurate enough for use or capable on their own for predicting LMY% in lamb.

Hennessy Grading Probe

This probe is used extensively within the pig industry throughout Europe (Figure 12). It is likely that it would easily adapt to lamb carcases, measuring GR tissue depth with similar precision to the AUSmeat sheep probe. However, it was tested on its capacity to measure eye muscle depth and fat depth at the C-site. The probe is equipped with a light reflectance reader which can determine when the probe is passing through tissues of different type (fat and muscle). This device demonstrated poor capacity to measure these tissue depths separately, and therefore was not pursued commercially.

Figure 12. Hennessy grading probe

Fat-o-Meat'er I and II

The Fat-o-Meat'er I and II (Figure 13) were evaluated as a means of assessing fat and muscle depth at the GR site (over the 12^{th} rib, 11cm from the midline). The Fat-o-Meat'er I and II are probe-type devices which were developed and used successfully in the pig industry throughout Europe for the last 40 years but have never been used by the lamb industry. They are similar to the now redundant AUSmeat probe and the Hennessy probe. The upgraded and modified Fat-o-Meat'er II has a new probe sensor design and can measure depths down to 125mm with greater resolution. The software/hardware interface can be easily transported across to a lamb system for sorting of carcases into the chillers and allowing accurate feedback to lamb producers. Unfortunately both probes were not able to measure the GR site with sufficient accuracy.

Figure 13. Caramotec Fat-o-Meat'er II
(Photo courtesy of Carometec)

Ultrasound

Ultrasound is used extensively within the pig industry to capture eye muscle depth and fat depth at the C-site of the loin muscle (longissimus lumborum) and also LMY%. This device, while proven to measure fat depth, eye muscle area and yield effectively in pigs, is impeded by the natural tendency for air bubbles to be captured underneath the fascia at the surface of the lamb carcase. Until this problem is overcome, this device will not be commercially available for sheep.

Ultrasound is used on live sheep and lamb to determine eye muscle depth and fat depth of the loin at the C-site. It provides a moderately accurate means to predict the percentages of carcase components (LMY%). Ultrasound technology is useful for evaluating potential breeding animals by determining eye muscle depth and fat at specific age points related to the endpoint of market animals and is relevant to produce Australian Sheep Breeding Values.

Cut-based Yield Prediction

The idea of using the weights of selected indicator cuts to predict lean meat yield was also tested as part of the Sheep CRC program. These cuts were easily accessible in the boning room, and as would be expected, the more measurements that were taken, the greater was the precision of prediction—with an R^2 of 0.44 achieved for one cut combination. However, when using a combination of carcase weight, GR tissue depth, and only one other measurable component (Easy Carve Leg) for ease of implementation in the boning room, the precision fell to an R^2 of 0.27. Due to the logistics of implementing a cuts based system within a commercial boning room, the need for individual carcase tracking, and the relatively low gain in precision, this approach was not pursued.

Chapter 3

Economic benefits of producing carcases with high LMY%

This chapter outlines the significant economic benefits of increasing LMY% for producers, processors and retailers.

Lambs are normally sold on farm or in saleyards on a per head basis and/or direct to processors on carcase pricing grids using weight and GR tissue depth. As demonstrated in Chapter 2, these measures are poor predictors of final carcase LMY%. Final customer value is not distributed along the value chain accurately using these methods, resulting in unclear market signals to producers. Furthermore, these set price grids using GR depth and carcase weight have no capacity to reflect end customer value. Improvements in LMY% will become increasingly important when processors and retailers can access technology that is easily able to measure it.

For the most part, prime lamb producers say "if the processors and retailers will only pay us for what our animals are really worth, we will produce anything they want." Producers have been frustrated at the apparent lack of monetary differentiation among animals with great variation in quality and carcase composition. The term that has been used to describe defining specifications for markets and working to price, carcases and/or cuts for their individual merit, is value-based marketing. Without market differentiation, no real incentives are given for producers to purchase "better" breeding stock, to finish animals to better meet slaughter endpoints or for processors/retailers to trim lamb and avoid selling excess fat down the chain, and for retailers and purveyors to purchase products differently than in the past.

Benefits for producers

At present, LMY% is not commonly measured or paid for, however there are good reasons why producers should aim to improve the LMY% of their flock. Across a number of breeds, research has shown that fast growth and high muscle sires produce progeny with better feed conversion efficiency. Feed conversion efficiency is a measure of the kilograms of feed needed to be consumed to produce a kilogram of liveweight gain. Fast growing and higher yielding sires produce progeny with a higher feed conversion efficiency. For a pasture based system, this can mean as much as four weeks grazing, and for feedlots, up to two units of feed conversion. A 10mm reduction in GR tissue depth (i.e. carcase fat score 4 compared to 2) has been estimated to improve feed efficiency, with only 6kg of feed dry matter (instead of 8kg) required for every 1kg of liveweight gain. This is based on the increased efficiency of laying down muscle instead of fat. These lambs will reach target weights quicker and eat less to get there, therefore saving feed costs. In addition, these lambs can be finished to heavier weights without becoming overly fat and accruing penalties.

Improvements in LMY% will become increasingly more important for producers to achieve, if processors and retailers can easily measure it and therefore provide clear market signals discriminating for fat. A number of meat supply chains around the world have installed measurement systems that accurately predict carcase composition and have paid producers based on some combination of factors including carcase LMY%. An example of a processor paying for LMY% is major New Zealand Lamb processor Alliance Group Limited. The Alliance Yield Quality Contract pays yield premiums assessed for each primal (leg, loin, shoulder) for qualifying lambs between 14.5kg-21.2kg. Under this system which is paid all year round, each primal is individually assessed and has a different price which reflects the value of the cuts within that primal. For each primal, there is a minimum yield % (threshold) the primal needs to achieve to qualify for the yield payment and then every 0.1% increase in yield will increase the dollar amount payable. The Danish Meat Research Institute reported an improvement in average pork carcase yield of 2.28% over a 10 year period after the installation of accurate yield measurement and reward systems. For the Australian Lamb industry, Sheep Genetics predicts that LMY% is currently increasing by 0.1% p.a. or 1% over 10 years.

Payment of incentives for higher LMY% by the processor to the producer will encourage more intense selection pressure to increase LMY%. Those producers able to achieve a higher LMY% in the percentage of their lambs will receive a premium and therefore increase profit. Previously, Australian processors have used VIAScan to incorporate a LMY% bonus payment into their grid payment system to reward higher LMY%. Although no Australian processor is currently paying a bonus for higher LMY%, there are LMY% payment systems offered by processors in New Zealand. Importantly, many of the New Zealand producers supplying this processor value the feedback they obtained on the LMY% of their carcases.

Benefits for processors

For processors a high-yielding animal represents increased efficiency in the boning room. These carcases require less labour to trim fat and there is less carcase wastage. If processors and/or retailers have to trim off fat equivalent to, say, 5% of the weight of saleable meat, their yields are correspondingly reduced. Most processors offer price grids that take account of both carcase weight and fatness.

Knowing the LMY% of a carcase also enables the processor to match carcases to product lines by sorting carcases into specific consumer cutting lines. Carcase sorting significantly improves abattoir efficiency, particularly for export abattoirs that have a wider intake of diverse carcases. At present, lamb boning operations predominately sort carcases based on fat score and carcase weight alone. It has been suggested that these minimal sorting standards focus more on gross volume of meat and limit the value realised for many carcases. This lack of fabrication precision not only limits the true value potential of the carcase but also limits clear market signals to producers about carcases that provide the best consumer value. The use of LMY% to sort carcases will enable selection of higher yielding carcases for the more highly processed specifications while the remaining carcases can fill the less processed specifications.

Carcase grading technologies such as VIAScan in Australia or the Danish Ultrasound technology can be used for carcase sorting prior to chilling for fabrication optimisation. However, to date in Australia, VIAScan has only been used for producer feedback and hence industry has only realised 50% of its value.

Understanding how and when yield becomes an important driver of profit for different carcase types is important for processors considering implementation of yield based incentives and for anyone providing support in structuring such systems. So therefore, unless processors believe that increasing LMY% benefits them on a carcase basis, have a means of calculating the benefit and have a cost effective means of implementing payment systems, then payment structures for producers will continue to send the wrong market signals. The Sheep CRC has developed the Lamb Value Calculator as a means to demonstrate the value of LMY%. This tool is commercially available to assist processors to realise the value of LMY% for their business.

Benefits for retailers

Producing a high yielding lamb carcase with known LMY% will enable the retail sector to improve efficiencies and process product to defined retail specifications and meet consumer demand. Consumers want to purchase cuts of meat that display a high quantity of red meat with less bone and subcutaneous fat, which is most efficiently achieved by producing leaner, more muscular animals on farm for slaughter. Consumers are also demanding more retail ready lamb products which require leaner carcases, because they are often produced from single muscles or two muscle groups (Trim Lamb Topsides, Rounds, Rumps etc.) rather than multi–muscled cuts such as a traditional leg of lamb.

To meet current retail specifications, the retail sector requires the following:

1. Firstly, to reduce fat waste from the cuts they further process. A higher yielding lamb will have lower excess external and seam fat. Loin products in particular are viewed as having too much fat cover.
2. Secondly, by controlling fat on products that require a high degree of fabrication, the cut accuracy of closer trimmed subprimals is improved, compared to the regularly trimmed commodity products resulting in less wastage. For example leaner carcases will see less waste when a simple bone-in leg is cut up into rumps, rounds and chump chops.
3. Thirdly, by knowing the LMY%, retailers can better match carcases to product lines, as the retail sector requires product that is consistent for weight, shape and size. By optimising carcase weight and LMY% the occurrence of excessive or underweight lamb cuts will be reduced.

The Lamb Value Calculator

Meat & Livestock Australia and the Sheep CRC have developed the Lamb Value Calculator to estimate the gross profitability of different carcase bone out specifications. This calculator is used with supply chains to demonstrate the benefits of increasing LMY% for retailers and processors. The Lamb Value Calculator is available on request and requires a consultation with Sheep CRC staff.

The calculator is underpinned by the relationship of the Hot Standard Carcase Weight (HSCW) and the GR fat depth with primal weight, to estimate the weights of selected cuts for both Merino and Cross-breed (XB) lambs. The estimated primal weights are based on boning data previously collected in Australia by MLA. The user can select cut specifications (spec), which may consist of a range of product, from bone in to completely denuded muscles. The final piece of information that must be entered into the program is the actual retail price of the selected cuts. The calculator provides an estimate of the gross profitability of a carcase, taking into account the cost of production from acquisition of the carcase through to the boning room. The calculator has additional analysis tools and charts that will assist the user to identify the main drivers of carcase profitability. An additional benefit is that hypothetical scenarios can be assessed to evaluate their effect on gross profit at a cut level, primal region level and whole carcase level.

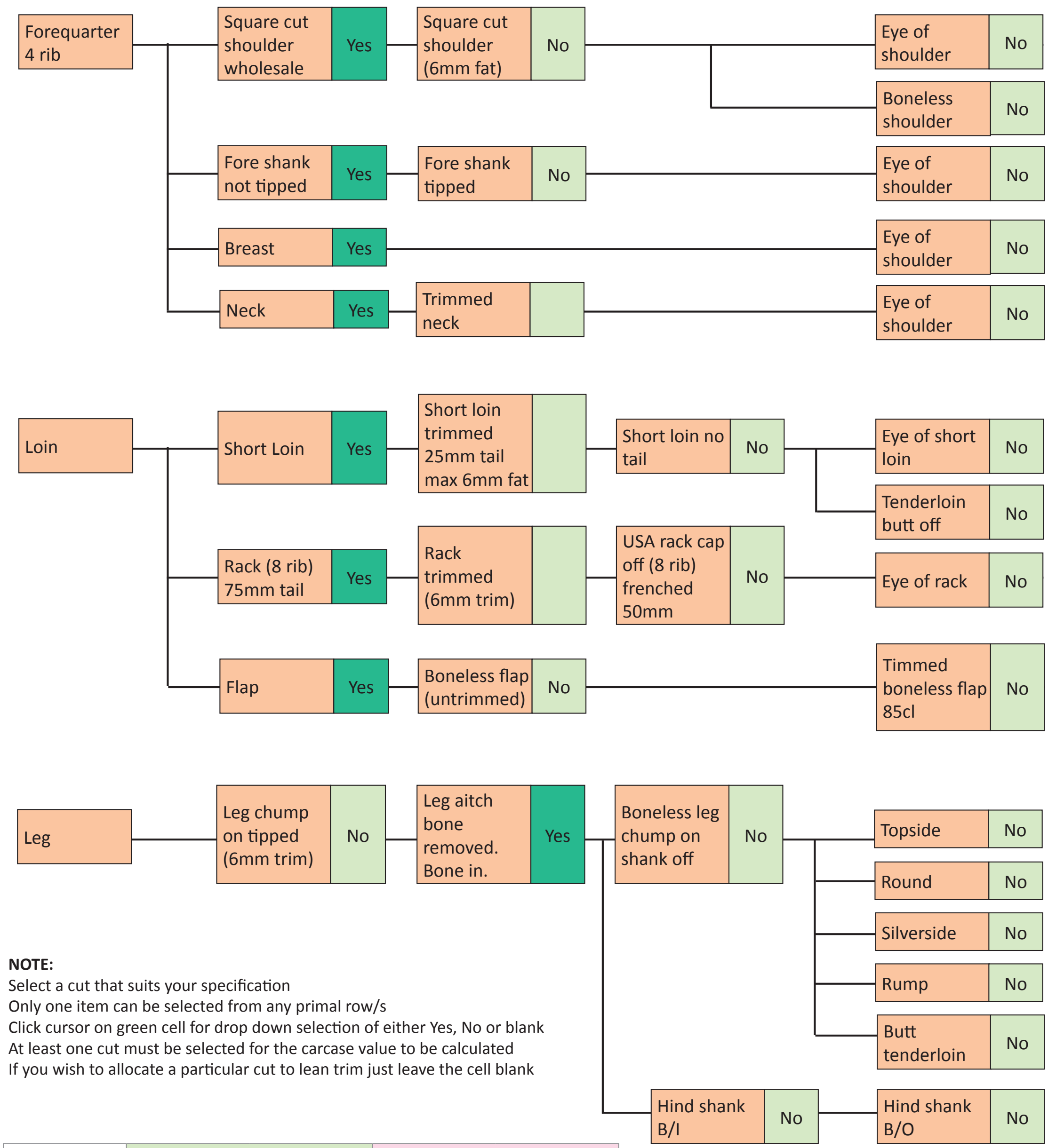
Impact of carcase weight and fat score on retail value for cuts

The Lamb Value Calculator can be used to determine the profitability of different cutting regimes. In the following example, high and low specification (spec) cuts for three different HSCW (18, 22, 26kg) and two different fat scores (fat score 2 and 4) are examined. The high level of fabrication is typical of a bone out for a retailer, whereas the low level of fabrication is typical of a predominately export orientated processor selling meat as primals. The different cutting lines for the two specifications are detailed in the lamb value calculator format (Figure 14 and Figure 15). The additional costs of fabrication include the extra labour costs.

Define Cut Specification Trade: Over the Hooks X-Breed Av. GR: 6mm Av. HCW: 26kg Shrinkage: 2.5%

Total Retail Value: $147.70

Carcase Gross Profit: $14.84 28.3%



NOTE:
Select a cut that suits your specification
Only one item can be selected from any primal row/s
Click cursor on green cell for drop down selection of either Yes, No or blank
At least one cut must be selected for the carcase value to be calculated
If you wish to allocate a particular cut to lean trim just leave the cell blank

	Carcase Composition		Retail Analysis	
Primal Region	**Weight (kg)**	**Yield %**	**Value ($)**	**Propn (%)**
FQ	8.720	34.4%	$28.84	19.5%
Loin	7.754	30.6%	$43.33	29.7%
HQ	7.471	29.5%	$74.71	50.6%
Lean trim	0.066	0.3%	$0.23	0.2%
TOTALS	**24.011**	**94.7%**	**$147.70**	**100.0%**

Variance to Yield Definition	Yes/No
Allocate lean trim to primal regions	No
Remove flap from yield specifications	No

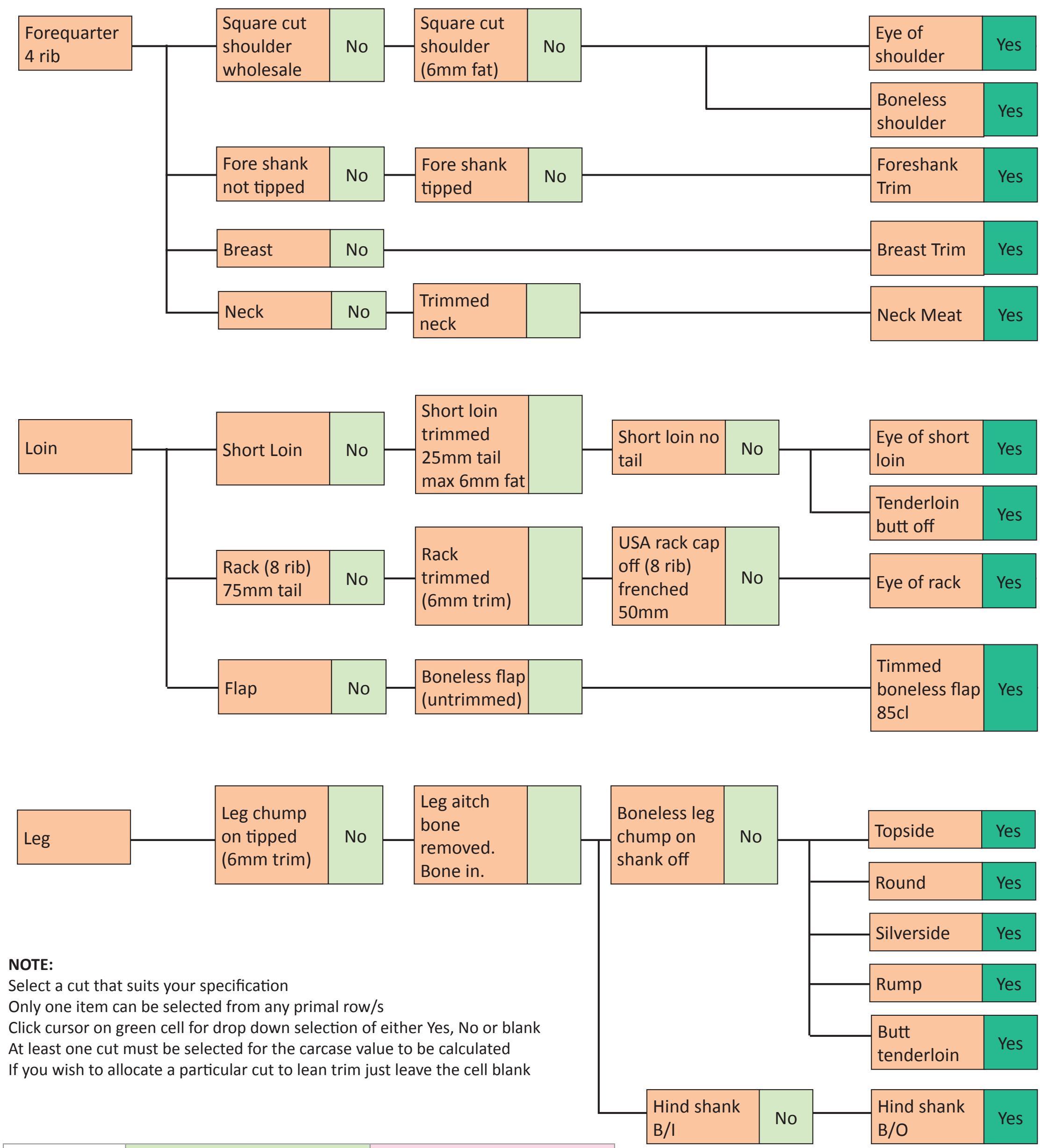
Figure 14. Low level of fabrication in Lamb Value Calculator

Define Cut Specification

Trade: Over the Hooks **X-Breed** **Av. GR: 20mm** **Av. HCW: 26k** **Shrinkage: 2.5%**

Total Retail Value: $261.76

Carcase Gross Profit: $157.32 60.1%



NOTE:
Select a cut that suits your specification
Only one item can be selected from any primal row/s
Click cursor on green cell for drop down selection of either Yes, No or blank
At least one cut must be selected for the carcase value to be calculated
If you wish to allocate a particular cut to lean trim just leave the cell blank

	Carcase Composition		Retail Analysis	
Primal Region	**Weight (kg)**	**Yield %**	**Value ($)**	**Propn (%)**
FQ	4.148	16.4%	$72.61	27.7%
Loin	3.144	12.4%	$81.67	31.2%
HQ	4.824	19.0%	$103.85	39.7%
Lean trim	1.035	4.1%	$3.62	1.4%
TOTALS	**13.150**	**51.9%**	**$261.76**	**100.0%**

Variance to Yield Definition	Yes/No
Allocate lean trim to primal regions	No
Remove flap from yield specifications	No

Figure 15. High level of fabrication in Lamb Value Calculator

The results outlined in Table 4 indicate that a leaner carcase (fat score 2) results in greater whole carcase profitability when the carcase is broken down into both high and low specification cutting lines compared to a fatter carcase (fat score 4) at all carcase weights.

For example, for a 22kg carcase, the difference in value between fat score 2 and 4 for the low spec trim was $3.25 (or 2.67% of the difference). Similarly, for the high spec trim there was an additional $16.86 in value to be gained by cutting a fat score 2 carcase compared to a fat score 4 (or 7.6% difference in value).

Table 4. Whole carcase profitability for low and high levels of fabrication for various carcase weights.

Low level of fabrication				
	Fat Score 2 (GR = 6mm)	Fat Score 4 (GR = 20mm)	Difference	% Difference (Fat Score 2 vs 4)
HSCW = 18	$102.52	$100.91	$1.61	1.60%
HSCW = 22	$125.11	$121.86	$3.25	2.67%
HSCW = 26	$147.70	$142.80	$4.90	3.43%

High level of fabrication				
	Fat Score 2 (GR = 6mm)	Fat Score 4 (GR = 20mm)	Difference	% Difference (Fat Score 2 vs 4)
HSCW = 18	$194.79	$181.79	$13.00	7.15%
HSCW = 22	$238.63	$221.77	$16.86	7.60%
HSCW = 26	$282.46	$261.76	$20.70	7.91%

Chapter 4

Biology of LMY%

The optimal carcase composition is one that has the minimum amount of bone, the maximum amount of muscle and optimum level of subcutaneous and intramuscular fat. In sheep, there are fat deposits under the skin and on the carcase surface (subcutaneous), fat deposits surrounding organs (e.g. kidney, heart), fat deposits between muscles (intermuscular fat) and fat deposits between the muscle fibre bundles of a muscle (intramuscular fat).

The main carcase tissues (fat, lean and bone) comprise approximately 50% of sheep live weight. Live weight as a function of age/time increases in a sigmoidal pattern as shown in Figure 16. The rate of increase in live weight accelerates from birth until a point of inflexion, whereupon it decelerates until the animal reaches maturity.

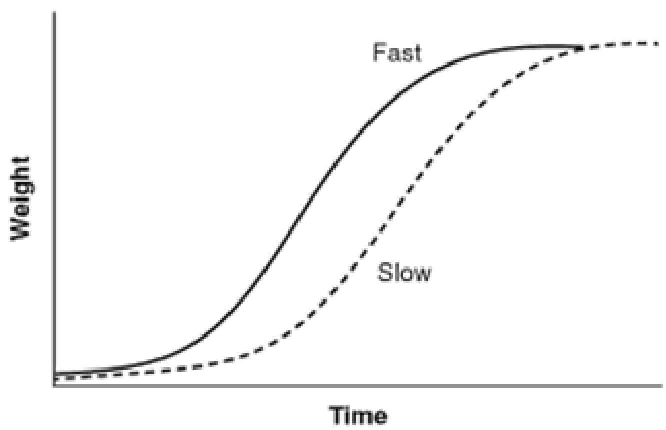


Figure 16. A sigmoidal growth pattern from birth to maturity for fast and slow growing animals

(Reprinted with permission from Boggs et al. (1998). Copyright Kendall/Hunt Publishing Company)

Fat, lean and bone develop at different rates to each other and to the weight of the carcase as a whole. At different time points during the progression to maturity the carcase will be composed of different proportions of lean, fat and bone. Maturity can be defined as the state of anatomical equilibrium achieved when an animal has ceased to grow or has reached its final mature body size.

Maturing patterns of tissues can be viewed in a graphical form (Figure 17) by assessing the rate at which carcase tissues mature relative to the rate at which body weight matures. Bone is the earliest maturing tissue (i.e. has a low growth impetus) and is the most developed of the three tissues at birth. As the animal progresses to maturity, the weight of bone as a portion of the whole carcase weight decreases. Fat is the least developed at birth and increases slowly at first, but the rate increases as the animal gets older. Therefore, fat is said to be late maturing relative to body weight, essentially becoming a larger portion of the carcase weight as the animal proceeds to maturity. Muscle develops at a similar rate to that of the whole carcase, but as the animal reaches maturity the muscle weight does become a decreasing portion of the carcase weight. Muscle is considered to have an average growth impetus, or is average maturing, as the increments in muscle weight are similar to the increments in body weight as the animal matures. Therefore the percentage of muscle in the body remains relatively constant as the animal grows from birth to maturity.

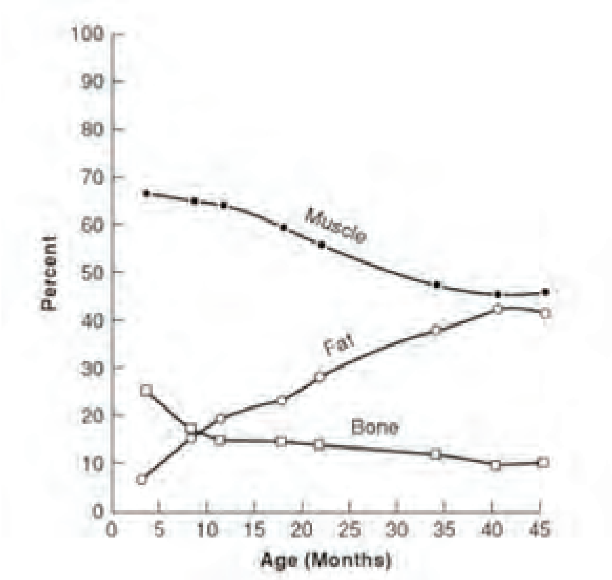


Figure 17. Changes in percentage body composition as a function of age
(Adapted from Butterfield et al. - 1988)

The distribution of each of these tissues within an animal is also influenced by maturity. For example the spinal musculature is relatively early maturing and therefore less mature animals will have proportionately more lean tissue within the saddle/loin region of the carcase. As animals approach maturity however, the spinal musculature will actually comprise a decreasing proportion of the total musculature. The major limb bones make up a progressively smaller component of total bone weight as animals mature. In contrast lumbar vertebrae increase as a proportion of total bone weight from 20% of maturity. This is different to that of the surrounding musculature, which decreases as a proportion of the total muscle weight during this time.

Fat is deposited at a lower rate than muscle growth during the first periods of postnatal life and at a greater rate than lean tissues when animals get older. However the proportional distribution of fat between carcase pools is found to be constant over a wide range of carcase fat contents, indicating that the major fat depots grow in the same proportion as animals fatten. The concentration of intramuscular fat increases later in an animal's life, not because it is 'late maturing' relative to other fat depots, but because fat is deposited at a greater rate than lean tissues later in life. Therefore, the concentration of fat in muscle will inevitably increase later in an animal's life.

Growth phases in a prime lamb operation

In the context of a prime lamb finishing system, the growth of the young lamb can be regarded as having four phases:

- Milk feeding (very efficient)
- Weaning (may involve a period of low growth rates due to stress of weaning)
- Pre-finishing
- Finishing (fat deposition rapidly accelerates)

In a typical commercial Australian sheep meat operation, lambs generally enter the 'finishing phase' between 30–35kg live weight, with females at the lighter weights. As defined above, there is a relatively constant rate of lean deposition in the body, which slows down as animals reach maturity. This slowing is likely to coincide with the finishing phase. Fat deposition, being late maturing, becomes a dominant process during the finishing phase. Therefore, for a typical lamb, most of the early weight gain development is lean tissue. However, as the animal approaches maturity (Figure 17) the lambs get heavier and the proportion of fat increases significantly, whilst the proportion of bone declines and the proportion of muscle slightly declines.

Mature size

Animals have a predetermined 'mature size' which is programmed from the early embryonic stage of an animal's life. It is important to remember that mature weight may be influenced by many non-genetic factors such as: nutrition, disease, physical environment, activity, social environment, and age. Optimal nutrition, for example, is necessary for maximum expression of genetic characteristics for mature size.

Due to the differences in the rates of development of the different tissues the composition of a carcase will vary as the animal matures. The time taken for two animals of different mature sizes to reach their mature weights is different. An animal of large mature size takes a longer time to reach its mature weight than the animal of small mature size. Considerations regarding maturity are important when trying to determine the differences (or similarities) in LMY% between two different groups of animals. Due to the differences in the tissue maturation rates, this can give misleading information about the effect that different genetics, sex or breeds have on the composition of the sheep. In animals of different mature weights, tissues that mature at a rate different to that of the body as a whole will comprise a significantly different portion of the carcase weight if comparisons are made at an equal body weight. Interestingly, at maturity, large and small sized breeds will have different weights of tissues, but when expressed as a proportion of live weight, there is no difference between the types (Table 5).

Table 5. Mature weight and percentage composition of rams from large and small mature size Merino strains

(Butterfield et al 1983)

	Merino Strain	
	Large Mature Size Merino	**Small Mature Size Merino**
% Muscle	22.3	22.8
% Bone	5.5	5.5
% Carcase fat	23.0	20.5
Mature live weight (kg)	116.5	90.9

Sex differences

Sex effects on body composition can be viewed using the same concept of mature weight, mature composition and maturing patterns for individual tissues. The issue of comparing sex differences is complicated with very few studies comparing rams, wethers and ewes all in the same study. However, irrespective of nutrition at maturity, rams had significantly more muscle (lean) and bone but less fat than the females. Rams are generally 1.4 times the mature weight of females (i.e. 40% heavier) (Table 6). In addition, ewes were significantly fatter than wether lambs.

Table 6. Percentage body composition in mature Merino rams and ewes

(Thompson et al 1984)

Tissue Component	Sex	
	Rams	Ewes
% Muscle	26.7	24.0
% Bone	6.3	5.6
% Carcase Fat	29.5	38.3
Mature live weight (kg)	70.0	49.0

Entire males and females have differences in maturity patterns for the tissues relative to bodyweight. The major difference appears to be post-puberty with rams being heavier than ewes in three muscle groups associated with the neck musculature. Rams have an increased growth impetus of the muscles in the cranial or neck region and with proportionately less muscle in the hind region. Studies indicate rams required a larger muscle mass in the neck region to support a larger head and horns and exert their dominance.

Table 7 shows that after adjustment for the increased weight of the head and horns and testes in the rams, rams and wethers had a similar mature weight, although there were large differences in mature composition. Because there was no difference in mature size, comparisons were similar whether they were made at the same stage of maturity or body weight. Overall, rams were leaner than castrates at all stages, with the magnitude of the difference increasing with increased live weight (or stage of maturity).

Table 7. Mature body composition of rams and wethers

(Butterfield et al 1985)

Tissue Component	Sex	
	Rams	Wethers
% Muscle	24.8	22.9
% Bone	4.7	4.2
% Carcase fat	24.8	30.0
Mature live weight (kg)	99.7	95.9
Head plus horns (kg)	6.2	3.4
Testes (kg)	0.3	
Mature live weight minus head and testes (kg)	93.2	92.5

Irrespective of nutrition, there is a tendency for female lambs to fatten sooner than wethers. Ewe carcases weighing 25kg typically contain 2–3kg more fat than castrated males and this will reflect in a lower LMY% for females, consistent across breeds. 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.

Nutrition

Nutrition affects LMY% by influencing the final carcase weight, but also by affecting the composition of the carcase at any given weight. Alterations in growth rate arising from differences in the overall plane of nutrition can alter body fat and protein content and the eating quality of the meat produced.

Pre-weaning nutrition has been shown to impact carcase composition. Animals that experience inadequate nutrition early in their life (prior to weaning) have the potential to end up fatter post-weaning, because the growth impetus of fat is at its 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.

Lambs that grow at greater than 250 grams/head/day (g/h/d) may be considered fast growth. If growth rates are sustained at these levels then these lambs will move into the fattening phase at an earlier stage of maturity. Once lambs enter the fattening phase, there is little change to the muscle:bone ratio, and therefore most of the impacts on LMY% of feeding, are an increase in lamb fatness. Meat Standards Australia (MSA) recommendations for post-weaning growth rates to ensure optimal meat quality are >100g/h/day for crossbred lambs and 150g/h/d for Merino lambs.

Chapter 5

Using genetics to produce high LMY% carcases on farm

It is commercially desirable to produce lambs that have a smaller portion of their carcase comprising of fat. Excessive fat is undesirable for consumers and processors as there are associated costs with its trimming from the carcase. The feed costs associated with continued growth of the more mature animal are considerable and the tendency for fat deposition increases as an animal ages. As a result it is beneficial to produce lambs that have a larger proportion of their carcase as muscle at an early age.

LMY% is influenced by a combination of the animal's genetics and the environment in which it's grown. This chapter will focus on improved genetics but it is important to note that the improved management of feed supply and quality and subsequent growth rate of lambs and better animal health will also contribute to higher LMY%.

Improved genetics—the basics

Growth rate and leanness are heritable. Genetically faster growing and leaner rams and ewes breed faster growing and leaner lambs. Faster growing lambs also reach heavier weights earlier.

A frequently asked question is: "Which breed is best for yield?" The answer is that no one breed will be better or worse. The variation that exists within a breed is greater than the variation that exists across breed types. Improvements in yield will result from careful selection of the right animals within each breed. Seedstock breeders (studs) are constantly striving to improve the information that they can provide to clients to meet their breeding objectives.

Increasing growth rates through breeding will produce lambs that reach target weights more quickly, but when there is no selection emphasis on fat or muscle, higher LMY% will not necessarily result. Therefore, a combined approach of selecting for higher growth, decreasing carcase fatness (increased leanness) and increased muscling is required to produce higher LMY%.

Figure 18 shows two carcases from Sheep CRC flocks that had similar carcase weight (23 and 23.6kg) but different fat scores (2 and 4 respectively), and considerable differences in GR fat and saleable meat yield. The score 2 lamb had 10mm fat at the GR site and 56% saleable meat, whereas the fat score 4 animal had 20mm fat and 48% saleable meat; the leaner animal produced 2kg more lean meat than the fat animal.

The key to making improvements in LMY% is to access feedback information for carcase weight, fat and if possible LMY% for sheep that have been sold over the hooks, and use this information to make informed decisions when purchasing genetics.

Lean meat yield% - Less fat!

Score 4

- Carcase Wt: 23.0kg
- GR: 20.0mm
- Fat weight: 6.87kg
- Saleable meat weight: 10.34kg
- Saleable meat yield: 48%

Score 2

- Carcase Wt: 23.6kg
- GR: 10.0mm
- Fat weight: 4.86kg
- Saleable meat weight: 13.08kg
- Saleable meat yield: 56%

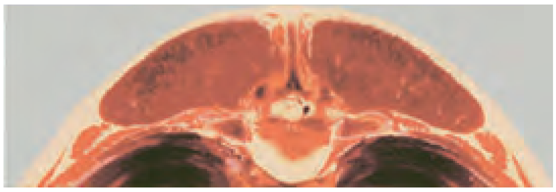


Figure 18. The impact of LMY% on saleable meat weight for a fat score 2 verses a fat score 4 lamb

Using Australian Sheep Breeding Values to improve LMY%

Sheep Genetics produces Australian Sheep Breeding Values (ASBVs), which are used to predict the genetic merit of a sire for many economically significant production traits (carcase, wool, reproduction). These provide a simple picture of the value of an animal's genes for a production trait. ASBVs are based on the animal's own measured performance and that of its relatives. For each trait the ASBV is shown as a positive or negative difference from the breed base, which is set at zero. The average ASBVs for different traits change over time as a breed makes genetic progress. An ASBV can be directly compared across age groups and flocks, which is not possible if using raw measurements alone.

ASBVs for LMY% have been developed with the intention of these ASBVs being used in commercial production systems in the future. A positive LMY ASBV is associated with a higher LMY%. Additional ASBVs have also been developed for shear force (tenderness) and intramuscular fat (IMF).

Until recently, industry has used ASBVs that indirectly select for lean meat yield: post weaning weight (PWT), C-site fat depth (PFAT) and eye muscle depth (PEMD).

Post weaning weight (PWT)

Post weaning weight ASBVs describe the animal's genetic merit for growth rate and are reported in kilograms. The higher this ASBV, the greater the genetic potential of that animal to grow quickly. This will mean that progeny from sires with a higher PWT ASBV will be heavier at a constant age.

Post weaning fat depth (PFAT)

Post weaning C-site fat depth ASBVs describe the fat depth of an animal at a constant weight and are reported in millimetres. This means that progeny from a more negative Fat Depth ASBV sire will be leaner at a constant weight. A negative change of 1mm in a PFAT ASBV is estimated to lift LMY% by 0.5%–1.0%.

Post weaning eye muscle depth (PEMD)

Post weaning eye muscle depth ASBVs describe each animal's genes for eye muscle depth at constant weight. This means that progeny from Sires with a more positive PEMD ASBV will be genetically heavier and more muscular. There is a direct and extremely high genetic correlation between eye muscle depth and eye muscle area—effectively, using one is the same as using the other.

Using Sheep Genetics Indexes

Selecting rams for a breeding program to improve LMY% will involve consideration of several traits, not just Eye Muscle Depth (PEMD) as this alone will not improve LMY%. ASBVs can be combined into a 'selection index', which gives the best overall basis for selecting breeding stock to achieve production goals. Combinations of ASBVs are used to create selection indices for ranking sires to suit different production goals.

Commercially used indices for improving LMY% are 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.

Carcase Plus Index

The Carcase Plus Index is a desired gains index made up of post weaning information, which is the age at which most lambs are slaughtered. This index rewards high growth and muscle depth while at the same time rewarding for increased leanness. The ASBVs which contribute to this index and their proportions are: NWT 30%, PWT 35%, PFAT 5% and PEMD 30%.

Trade and Export $ Indexes

Trade and Export $ Indexes are expressed as dollars per ewe joined per year. In estimating the dollar variation the index assumes a weaning rate of 100% and lamb at $3.50kg cwt. Table 8 shows the components that go into calculating these two indexes:

- The Trade $ Index is designed to target production of 20kg carcase weight lambs and uses post-weaning age (7.5 months) ASBVs for growth, fat and eye muscle depth to produce the $ Index value.
- The Export $ Index is aimed at producing 26kg carcase weight lambs and like the Trade $ Index uses post-weaning age (7.5 months) ASBVs for growth, fat and eye muscle depth to produce the $ Index value.

Table 8. Carcase weight and ASBV targets for Trade and Export $ Indexes

	Trade $	Export $
Carcase weight target	20 kg	26 kg
Post weaning weight ASBV	≥ +6	≥ +10
Post weaning fat depth ASBV	Optimised at–0.5	Optimised at–1.0
Post weaning eye muscle depth ASBV	≥ 0	≥ 0

Lamb 2020 Index

The Lamb 2020 Index is constructed as a dollar index rather than as a desired gains index like Carcase Plus. Dollar values for growth (carcase weight), fat and muscle have been calculated on an assumed 22kg carcase weight. This index has been designed to be different to the Carcase Plus index, however it still has a high correlation (R^2 = 0.9) due to the emphasis on growth and muscle. With more producers targeting earlier turn-off ages, the relative value for growth in this index was split 40:60 between weaning weight (WWT) and post weaning weight (PWT). In an attempt to limit further increases in birth weight, a negative $ emphasis was placed on increasing birth weights- a result from directly selecting for growth (noting that there is a positive correlation between growth (WWT and PWT) and birth weight (BWT)). The addition of PWEC (worm egg count ASBV) to LAMB2020 was driven by the fact that internal parasites are one of the most significant costs to the Australian sheep industry. The Lamb 2020 Index is therefore made up of: BTW (birth weight kg) 8%; WWT (kg) 24%; PWT (kg) 25%; PFAT (mm) 9%; PEMD (mm) 22%; PWEC (%) 12%.

Sheep Genetics provides some specifications and general recommendations for cutoffs and selection criteria on a range of ASBVs for producers, along with reasons for their recommendations as shown in Table 9. Note that these are general guidelines, and breeders should make adjustments for their personal situation and consult with their ram breeders to determine the most appropriate sire selection.

Table 9. Sheep Genetics recommendations to improve LMY by matching terminal sires to ewe base and target market

<table>
<tr><th>Domestic Trade Weight</th><th colspan="5">Trade $ Index values of 109 or above.
The Trade $ Index aims to optimise growth, fat and muscle for a 20kg carcase weight lamb.
Specific traits should fall roughly within the ranges shown below.</th></tr>
<tr><td rowspan="4">Lambs from XB ewes
18–22kg CWt</td><td>BWT</td><td>PWT</td><td>PFAT</td><td>PEMD</td><td>Carcase Plus Index</td></tr>
<tr><td>+0.5 or below</td><td>12 or above</td><td>-1 to 0</td><td>+1.2 or above</td><td>175 or above</td></tr>
<tr><td colspan="5">Note: If PWT is greater than 14 then PFAT range should be greater than-0.5.</td></tr>
<tr><td colspan="5">If rams are being mated to maiden ewes, BWT may need to be below +0.4. Rams with higher post-weaning weight ASBVs will produce lambs with faster growth rates and will have greater carcase weights at given ages. As new season lambs from 1st cross ewes are usually fatter, rams should have lower ASBVs for fat to compensate for this effect. However, if sires ASBVs for growth are high, the ASBVs for PFAT should not be as low.</td></tr>
<tr><td rowspan="3">Lambs from Merino Ewes
18–22kg CWt</td><td>BWT</td><td>PWT</td><td>PFAT</td><td>PEMD</td><td>Carcase Plus Index</td></tr>
<tr><td>+0.4 or below</td><td>12 or above</td><td>-0.7 to +0.5</td><td>+1.2 or above</td><td>175 or above</td></tr>
<tr><td colspan="5">If rams are being mated to maiden ewes or small framed ewes, BWT may need to be below +0.3. In general rams selected to mate to Merino ewes should have slightly higher growth and slightly higher PFAT values to compensate for the Merino genetics, particularly if the environment is such that the season is shorter. Emphasis on muscling should be moderate to high.</td></tr>
</table>

<table>
<tr><th>Export Weight</th><th colspan="5">Export $ Index values of 107 or above.
The Export $ Index aims to optimise growth, fat and muscle for a 24kg carcase weight lamb.
Specific traits should fall roughly within the ranges shown below.</th></tr>
<tr><td rowspan="3">Lambs from XB ewes
24kg + CWt</td><td>BWT</td><td>PWT</td><td>PFAT</td><td>PEMD</td><td>Carcase Plus Index</td></tr>
<tr><td>+0.5 or below</td><td>13 or above</td><td>-1.2 to 0</td><td>+1.5 or above</td><td>185 or above</td></tr>
<tr><td colspan="5">If rams are being mated to maiden ewes, BWT may need to be below +0.4. Getting 2 or 3 fat score 24kg plus lambs is a challenge. Sires with negative ASBVs for fat will produce leaner lambs. Selecting sires with higher growth rate and negative ASBVs for fat will produce higher yielding lambs. However, very low PFAT values may impact on eating quality.</td></tr>
<tr><td rowspan="3">Lambs from Merino ewes
24kg + CWt</td><td>BWT</td><td>PWT</td><td>PFAT</td><td>PEMD</td><td>Carcase Plus Index</td></tr>
<tr><td>+0.4 or below</td><td>13 or above</td><td>-0.1 to 0</td><td>+1.5 or above</td><td>185 or above</td></tr>
<tr><td colspan="5">If rams are being mated to maiden ewes or small framed ewes, BWT may need to be below +0.3. In general ASBVs for fat do not need to be as low as for XB ewes. However it is important that you look at your feedback sheets as there is significant variation in the genes for fatness and growth amongst Merino ewes.
In general Merino ewes may also be slightly poorer muscled so a little more emphasis on muscling should occur.</td></tr>
</table>

New ASBVs for LMY% and Eating Quality

At this stage, none of these traits are included in any of the standard LAMBPLAN or MERINOSELECT indexes. These new ASBVs are derived from a combination of the animal's genomic information from a 50k SNP Chip analysis, and measurements from other animals in the Sheep CRC Information Nucleus Flock. See Case Study in Chapter 6 for initial results of on-farm testing of these new Breeding Values.

Lean Meat Yield% (LMY - %)

This trait is a measure of the commercial yield of lean meat as a percentage of hot carcase weight. Lean meat yield is estimated from a combination of weight, muscle and fat dimensions and has been validated by either CT-scanning or through direct commercial bone-outs. LMY has a moderate heritability, with the normal range in lamb between 51 and 58%. The Research Breeding Valuss (RBVs) range around 0, with higher values indicating greater genetic potential for higher LMY.

Carcase weight (HSCW - kg)

This trait is a measure of hot carcase weight of the animal and reported in kilograms. HSCW is a function of live weight and the dressing percentage. HSCW is the primary method to determine payment of lambs that are sold over the hooks. The RBVs range around 0, with higher values indicating greater genetic potential for increased carcase weight.

Carcase EMD (CEMD - mm)

This trait is a measure of the eye muscle depth of the loin taken from a quartered carcase and reported in millimetres. It is adjusted to a constant weight—in this case carcase weight—in the same way that the PEMD breeding value is adjusted to constant live weight. This trait has been shown to influence LMY% and the weights of key muscle, particularly the loin muscle. CEMD is correlated with the ultrasonic measure of eye muscle (PEMD) taken on a live animal. The mean CEMD measurement from the Information Nucleus flock is currently 30mm, with a range of 17–45mm. The RBVs range around 0, with higher values indicating greater genetic potential for increased carcase muscling.

Carcase fat (CFAT - mm)

This trait is a measure of the depth of fat taken at the C site in a quartered carcase and reported in millimetres. It is adjusted to a constant weight—in this case carcase weight—in the same way that the PFAT breeding value is adjusted to constant live weight. This trait has been shown to influence lean meat yield and the GR tissue depth. The trait is correlated with the ultrasonic measure of C fat (PFAT) in the live animal, though it is not as strong as the relationship between muscle traits. The mean CFAT measurement from the Sheep CRC Information Nucleus flock is currently 4mm, with a range of 0.2–24mm. The RBVs range around 0, with lower values indicating greater genetic potential for reduced carcase fat cover.

Intramuscular fat (IMF - %)

This trait is a measure of the chemical fat percentage in the loin muscle of a lamb, and is often referred to as marbling. The preferred range in lamb is between 4 and 6%, with a current industry mean value of 4.3%. IMF has been shown to have a significant impact on the flavour, juiciness, tenderness and overall likeability of lamb. IMF has a moderate to high heritability and high negative correlation with shear force—how hard it is to cut through the meat (see below)—as IMF increases, so does tenderness. The measured range in Information Nucleus flock lambs is 2–7%. The RBVs range around 0, with higher values indicating greater genetic potential for higher IMF%.

Shear Force (SHEARF5 - Newtons)

This trait is a measure of the force or energy required to cut through the loin muscle of lamb after 5 days of ageing, and is reported in kilograms of force (Newtons). The trait has a moderate/high heritability, and a moderate correlation with tenderness in lamb. The preferred value for lamb is 3kg or less. The mean SF5 from the Information Nucleus lambs is currently 2.4kg with a range from 1.1–7.7kg. The RBVs for this trait range around 0—with lower values indicating genetic makeup for lower shear force, or more tender meat.

Incorporating Eating Quality and Yield Breeding Values when choosing terminal sires, allow animals to be selected directly for meat and carcase quality traits. Higher or more positive Intra-Muscular 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 (DR%) values are favourable. Sheep Genetics recommends selecting rams with IMF, SF5, LMY and DR% traits of 0 or above.

Dressing Percentage (DP - %)

This trait is a measure of the dressing percentage of an animal at a constant age. Dressing percentage is calculated from the carcase weight of the animal as a proportion of its pre-slaughter liveweight. A higher value for the ASBV indicates the genetic potential for a higher dressing percentage.

Chapter 6

Research findings and Implications

Information Nucleus Flock results—Implications for ASBVs and Indexes

From 2007–2012, the Sheep CRC program supported an Information Nucleus Flock (INF) at 8 sites across Australia. The INF represented a unique opportunity to assess the impact of genetic selection for increasing LMY% in a range of environments. Each year over the five-year research period, approximately 100 sires which were divergent for a range of traits, including the carcase ASBVs (PWT, PEMD and PFAT) were used to produce lambs at each of these sites. Animals were slaughtered at an average carcase weight of 21.5kg and a range of carcase and meat quality traits were measured. The impacts of PWT, PEMD and PFAT on various meat quality traits are listed below.

A subset of these carcases underwent CT scanning following their division into 3 primals (forequarter, saddle region and hindquarter). CT scanning allowed for an accurate determination of the quantities and distribution of fat, muscle and bone within the carcase and the impacts of key ASBVs on the distribution of lean, fat and bone between these sub-sections. Tables 10 to 12 summarise the differences in effects from Terminal, Maternal and Merino Sires.

Table 10. Carcase values of lambs out of Merino Sires

(Wether lambs bred from Merino dams, corrected for the same weight of approximately 23 kg)

	Weight in Kg				% Weight of section			
	Bone	Fat	Lean	Total section	Bone	Fat	Lean	$ Value lean
Fore section	1.52	1.90	4.37	**7.79**	19.72	24.61	56.57	**75.76**
Saddle section	0.93	2.60	3.53	**7.06**	12.91	36.18	49.03	**95.29**
Hind section	1.41	1.34	5.16	**7.92**	18.02	17.03	65.76	**104.57**
Total Carcase				**22.77**				**275.62**

Table 11.Carcase values of lambs out of Maternal Sires

(Wether lambs bred from Merino dams, corrected for the same weight of approximately 23 kg)

	Weight in Kg				% Weight of section			
	Bone	Fat	Lean	Total section	Bone	Fat	Lean	$ Value lean
Fore section	1.46	1.98	4.28	**7.72**	18.92	25.68	55.40	**74.19**
Saddle section	0.91	2.83	3.45	**7.19**	12.61	39.39	48.00	**93.30**
Hind section	1.36	1.39	5.10	**7.85**	17.30	17.71	64.99	**103.34**
Total Carcase				**22.77**				**270.82**

Table 12. Carcase values for lambs out of Terminal Sires

(Wether and ewe lambs, corrected for the same weight of approximately 23 kg)

Dam Breed	Lamb Sex	Fore section							
		Weight in Kg				% Weight of section			
		Bone	Fat	Lean	Total Fore section	Bone	Fat	Lean	$ Value lean
BLM	F	1.38	1.91	4.14	7.42	17.86	24.68	53.57	71.74
Merino	F	1.40	1.85	4.20	7.44	18.12	23.92	54.35	72.79
BLM	M	1.45	1.82	4.35	7.61	18.71	23.56	56.31	75.41
Merino	M	1.44	1.79	4.38	7.61	18.67	23.15	56.77	76.03
		Saddle section							
		Weight in Kg				% Weight of section			
		Bone	Fat	Lean	Total Saddle section	Bone	Fat	Lean	$ Value lean
BLM	F	0.90	2.94	3.59	7.43	12.44	40.94	49.94	97.07
Merino	F	0.91	2.82	3.64	7.37	12.67	39.19	50.54	98.23
BLM	M	0.92	2.65	3.67	7.24	12.81	36.84	50.99	99.11
Merino	M	0.91	2.57	3.70	7.19	12.68	35.79	51.49	100.08
		Hind section							
		Weight in Kg				% Weight of section			
		Bone	Fat	Lean	Total Hind section	Bone	Fat	Lean	$ Value lean
BLM	F	1.32	1.37	5.23	7.91	16.79	17.39	66.58	105.88
Merino	F	1.33	1.33	5.33	7.99	16.94	16.97	67.85	107.90
BLM	M	1.36	1.29	5.32	7.97	17.32	16.41	67.74	107.72
Merino	M	1.36	1.29	5.39	8.03	17.26	16.37	68.59	109.08

Dam Breed	Lamb Sex	Total Carcase weight (kg)	Total Carcase value ($)
BLM	F	22.77	274.69
Merino	F	22.80	278.92
BLM	M	22.82	282.25
Merino	M	22.83	285.19

The impact of ASBVs on the weight of the sections can be illustrated pictorially with Figures 19 to 21. (Note that the carcases shown in the diagrams below are visually the same, but are used to represent the various sections and the effect of the ASBV on that section by sire type).

PWT		PFAT		PEMD	
			+7.0% lean -19.6% fat +4.1% bone		+2.1% lean -14.4% fat
	+4.4% lean		+10.4% lean -23.8% fat +6.7% bone		+9.8% lean -14.2% fat
			+6.5% lean -14.7% fat +5.9% bone		-3.6% fat

Figure 19. Impact of ASBVs on carcase composition of Merino sired lambs

Values represent the percentage change in tissue weight across the range of ASBV within each section. The range represented for PEMD was -2.6 to +2.6, for PFAT was -1.9 to +1.9, and for PWT was -5 to 10.8.

PWT		PFAT		PEMD	
			+8.1% lean -24.9% fat +5.0% bone		+9.6% lean -11.9% fat
	+4.8% lean		+12.9% lean -29.5% fat +8.2% bone		+8.1% lean -11.8% fat
			+8.6% lean -18.2% fat +7.3% bone		-13.2% fat

Figure 20. Impact of ASBVs on carcase composition of Maternal sired lambs

Values represent the percentage change in tissue weight across the range of ASBV within each section. The range represented for PEMD was -2.5 to +1.8, for PFAT was -2.1 to +2.6, and for PWT was -6.1 to 12.4.

PWT		PFAT		PEMD	
			+14.4% lean -24.7% fat +5.1% bone		+8.4% lean -15.7% fat
	+3.7% lean		+13.2% lean -28.1% fat +8.4% bone		+14.7% lean -19.0% fat
			+8.3% lean -18.6% fat +7.5% bone		-15.4% fat

Figure 21. Impact of ASBVs on carcase composition of Terminal sired lambs

Values represent the percentage change in tissue weight across the range of ASBV within each section. The range represented for PEMD was -2.8 to +5, for PFAT was -2.5 to +2.3, and for PWT was 5.3 to 18.6.

Post weaning weight (PWT)

Lambs from high PWT rams will grow faster and reach heavier slaughter or target weights sooner than lambs sired by rams with lower growth ASBVs.

The impact of the PWT ASBV on composition has historically been linked to maturity at slaughter (Figure 22). Animals from high PWT sires will reach maturity later, before they enter the fattening phase. Therefore, lambs growing at a faster rate are proportionately leaner when compared at the same carcase weight. This is because lean, being an early maturing tissue, will comprise a larger portion of carcase weight compared to the late maturing fat.

However, the INF data indicated that these effects were small and restricted to the saddle musculature, with increased lean weight in the saddle region in all siretypes (Figures 19, 20, and 21). This redistribution could be explained by maturity with the spinal musculature being relatively early maturing, therefore, less mature animals should have proportionately more muscle in the saddle region than the average lamb.

There was a significant 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.

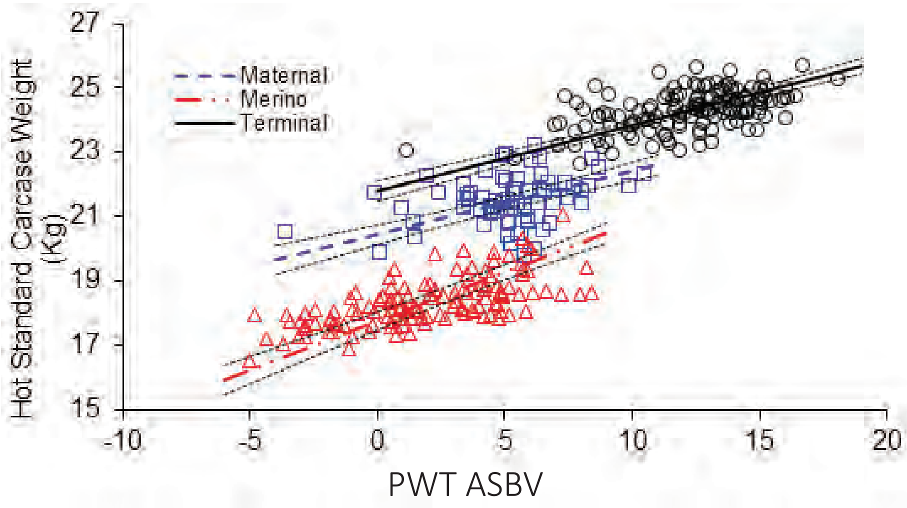


Figure 22. The association between hot carcase weight and the PWT ASBV (kg) within sire types

○ = Terminal sires; □ = Maternal sires; and Δ = Merino sires (Data courtesy of Sheep CRC)

Post weaning fat depth (PFAT)

Of the three carcase ASBVs, PFAT had the most broad-ranging impact on carcase composition, with these effects delivered consistently across all three sire types.

When compared at the same carcase weight, decreasing sire PFAT increased lean weight in all carcase sections, although these effects were proportionately greater in the saddle. The increases in lean were accompanied by increases in bone and offset by a reduction in fat in all carcase sections.

These effects are reflected through associated changes in fat depths and muscle weights. Thus, the progeny of high PFAT sires have heavier loin muscle weights, and reduced C-site fat depth and GR tissue depths. Previous research has demonstrated little genetic or phenotypic correlation between sire PFAT and adult weight, so it seems likely that these compositional differences will still be present when the animals reach their mature size.

Post weaning eye muscle depth (PEMD)

PEMD ASBV had marked effects on whole carcase LMY%. These were heavily focused on the saddle and hind sections, with no change in lean weight in the fore section (Figures 19–21).

This increase in lean weight was largely offset by decreases in fat in all sections of the carcase. This effect was quite consistent across all sire types (Figures 19–21).

The impact of PEMD ASBV on carcase composition aligns well with measurements of indicator muscles and fat depths in the saddle section. For example, in the progeny of Terminal sires, the weight of the loin muscle increased by 24.7 g (7.3%) and eye muscle area increased by 0.59 cm^2 (4.2%) across the 4.4mm range in Terminal Sire PEMD ASBV. Similarly, this was offset by decreases in C-site fat depth by 0.5mm (14%) across this same PEMD range.

This focused effect on loin muscle weight using selection for PEMD is particularly important for increasing carcase value, given that the loin is generally the highest value cut in both the domestic and international markets. Likewise, the lack of change in forequarter lean is less important as this musculature is less valuable. However, the reduction in fore section fat will be of great benefit given the propensity of forequarters to be too fat.

Carcase Plus Index

As the Carcase Plus index is based on WWT, PWT, PFAT and PEMD in ratios of 30:35:5:30 it largely reflects the combined effects of the three ASBVs but mostly the PWT responses.

Thus, increasing CP index leads to an increase in pre-slaughter live weight (HSCW) and dressing percentage, with a particularly strong impact in Merino lambs.

This represents an important industry message given the reliance of producers on this index value for directing Terminal ram purchase decisions. Currently, this index is not commercially available within the Merino industry, yet these results highlight the potential carcase gains that could be made if Merino producers made use of this index, which may be far greater than for producers of Terminal sired lambs. The impact of the Carcase Plus index on the composition of carcases of Terminal sired lambs can be seen below in Figure 23.

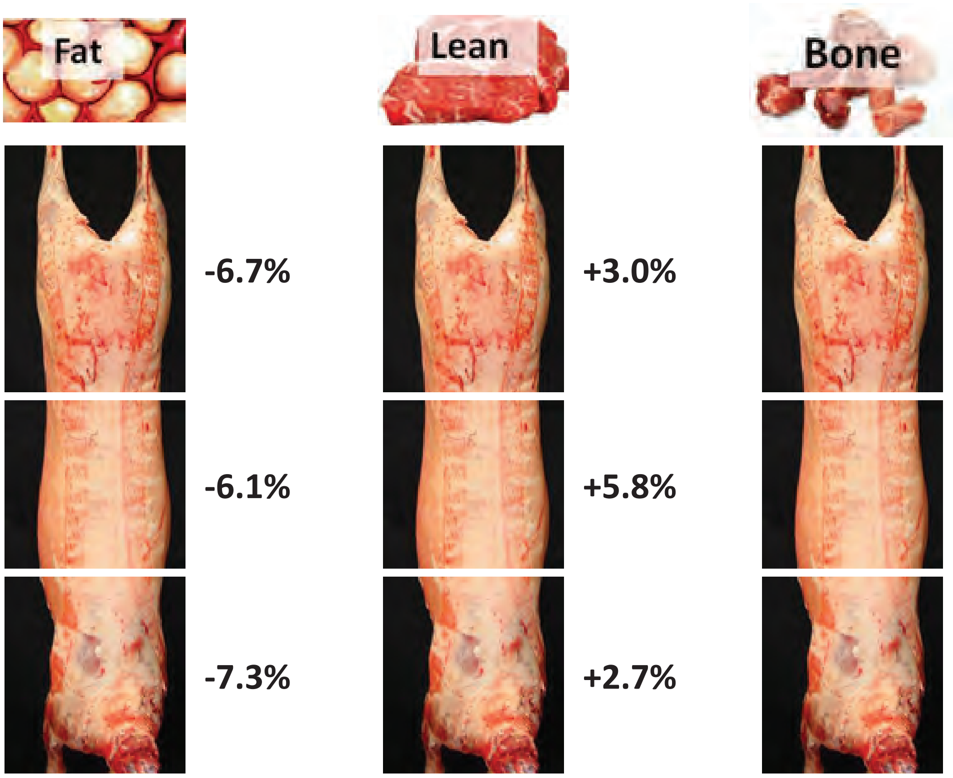


Figure 23. Impact of Carcase Plus Index on carcase composition of Terminal sired lambs

Values represent the percentage change in tissue weight across the range of ASBV within each section. The range represented for carcase plus index was 133 to 209.

Table 13 outlines the impact of the ASBVs PWT, PEMD and the Carcase Plus Index on various production factors such as birth, live weight and hot carcase weight. The change in each trait across the range of the ASBV and also the change per unit of ASBV are presented. For example, for the PWT ASBV which has a 23 unit range from highest to lowest ASBVs within the dataset, the birth weight increased by 0.016kg/PWT unit as PWT increased and the difference in birth weight between the lowest and highest PWT sires was 0.38kg. Whereas for PFAT, an increase in PFAT ASBV saw a reduction in birth weight of 0.068kg/PFAT and a difference of -0.34kg between the lowest and highest PFAT sires.

Table 13. The impact of ASBVs for PWT, PFAT, PEMD and the Carcase Plus Index on key meat production traits

PWT (23 unit PWT range)	Per unit change in ASBV (/PWT)	Change across the range of ASBVs used in dataset (ASBV increasing)	Specific effects (/PWT)		
			Merino sires	Maternal sires	Terminal sires
Birth weight	+0.016kg	0.38kg increase as PWT increased	0.81kg	0.29kg	0.06kg
Live weight	+0.46kg	10.7kg increase	0.68kg	0.37kg	0.34kg
HSCW	+0.24kg	5.52kg increase	0.35kg	0.18kg	0.18kg
Dressing Percentage	+0.38%				
C-site fat depth	-0.012mm	0.29mm decrease			

PFAT (5 unit PFAT range)	Per unit change in ASBV (/PFAT)	Change across the range of ASBVs used in dataset (ASBV increasing)
Birth weight	-0.068kg	0.34kg decrease as PFAT increased
Live weight	-0.44kg	22.2kg decrease
HSCW	-0.208kg	1.04kg decrease
Dressing Percentage	+0.28%	1.4% increase
C-site fat depth	+0.2mm	1mm increase
GR Tissue depth	+0.48mm	2.4mm increase
Loin weight	-4.1g	20.5g decrease
Eye muscle area	-0.092cm³	0.46cm³ decrease

PEMD (7 unit PEMD range)	Per unit change in ASBV (/PEMD)	Change across the range of ASBVs used in dataset (ASBV increasing)
Birth weight	No impact	
Live weight	No impact	
HSCW	+0.15kg	1.09kg increase as PEMD increased
Dressing Percentage	+0.24%	1.72% increase
Loin weight	+3.52g	24.7g increase
Eye muscle area (terminal sires 4.4mm rand in PEMD)	+0.13mm	0.59mm increase
C-site fat depth (terminal sires only)	-0.25mm	0.5mm decrease
GR tissue depth (terminal sires only)	+0.15mm	0.66mm increase

Carcase Plus Index (95 unit CP Index range)	Per unit change in ASBV (/CP)	Change across the range of ASBVs used in dataset (ASBV increasing)	Specific effects (/CP)		
			Merino sires	Maternal sires	Terminal sires
Live weight	+0.055kg	4.4kg increase as CP index increased	0.075kg	0.062kg	0.028kg
HSCW	+0.038kg	3.61kg increase	0.043kg	0.053kg	0.025kg
Dressing Percentage	+1.8%		0.032%	0.011%	0.013%

PWT: post weaning weight; PEMD: post weaning eye muscle depth; PFAT: post weaning C-site fat depth

What are genetics for growth worth?

Current top 10% PWT ASBV average is 13.4kg
Average PWT ASBV across industry is 10.7kg

↓

2.7kg ASBV difference in progeny liveweight between high PWT sires and average PWT sires

↓

1.35kg extra liveweight for every lamb sired by high PWT sire

↓

Average ram sires 180 lambs per lifetime

↓

= Extra 243kg liveweight from high PWT sire

Genetically elite turnoff quicker!

2000 crossbred ewes joined to terminal sires
% of lambs 43kg plus at 16 weeks

Sire Group	Av. PWT ASBV	43kg +
High PWT	8.9	46.6%
Mid PWT	4.4	18.0%
Low PWT	1.6	11.6%

Source: Sheep CRC & NSW DPI

Impacts on Eating Quality of selecting ASBVs for LMY%

An extensive sensory analysis was conducted on lambs slaughtered as part of the Sheep CRC Information Nucleus program. The data analysis of the effects of key ASBVs on eating quality has revealed the following:

- Increasing Sire PWT ASBV decreased the tenderness, overall liking, juiciness and flavour scores. PWT decreased tenderness across all sire types by 4.9, 4.0 and 5.3 units for the Terminal, Maternal, Merino sire types respectively. Increasing PWT at a constant slaughter reflects maturity, hence the negative association between PWT and some sensory scores might suggest that less mature and leaner lambs at the same age will be less acceptable to consumers.
- Decreasing PFAT was associated with reduced tenderness scores for the loin samples only with a 3.6 unit reduction in tenderness across the PFAT range. There was no impact of PFAT within the topside samples with this contrasting effect between the two cuts possibly due to the different IMF levels. PFAT is an important driver of LMY% and this result indicates that sires selected for decreased carcase fat are more likely to produce progeny with less tender meat.
- Increasing PEMD decreased tenderness, overall liking and flavour across all sire types by 5.3, 3.6 and 3.1 units for the Terminal, Maternal, Merino sire types respectively across the 7-unit PEMD range, within both the loin and topside samples. This result indicates that sires selected for increased carcase muscling (lean) are more likely to produce progeny with less tender meat, which is less flavoursome and overall less acceptable meat.
- Increasing sire PEMD was associated with a 0.36 unit increase in meat redness. The positive impact of increased muscling on meat colour may be associated with reduced oxidative capacity in high PEMD sires, likely in-part to be caused by altered myofibre differentiation in more muscled animals.

The key conclusion from these results is that as we continue to select for increasing LMY% it is important not to lose sight of meat quality and human health traits. Very lean, highly muscled animals may guarantee high LMY%, however such animals will be very susceptible to ‘cold shortening’ during refrigeration. Cold shortening may result when, prior to the onset of rigor mortis, carcases are subjected to rapidly lowered temperature which toughens muscle and disappoints consumers. This is why most processors penalise Fat Score 1 lambs.

Intramuscular fat (IMF) is of particular importance for eating quality and there is a strong positive correlation between IMF and PFAT. IMF is a key driver of consumer perception of tenderness, juiciness and flavour (Figure 24). Selection for leanness and muscularity has been shown to reduce IMF, which will adversely affect eating quality. The genetic correlation between LMY% and IMF and shear force (tenderness) is moderate/high and so it is crucial to have dual selection for both yield and eating quality.

A more negative PFAT ASBV is a very important driver of increased LMY% but a side effect will be lower IMF. Finding sires that are in both the moderate to high range for IMF RBV and negative PFAT ASBV will deliver higher LMY%, while maintaining eating quality. An Eating Quality Breeding Value may be developed in the future which is based on IMF and Shear Force.

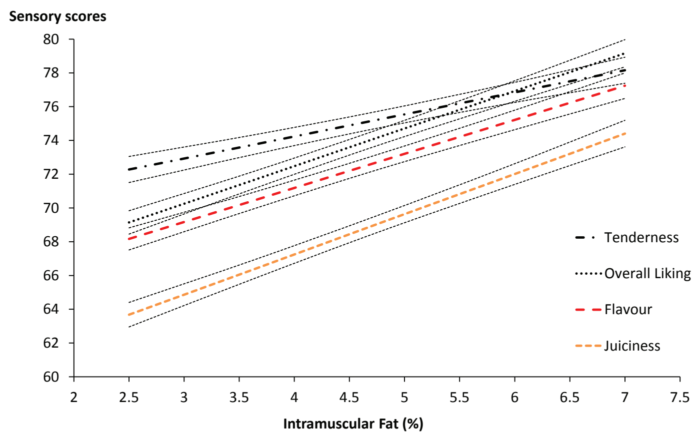


Figure 24. The association between sensory scores for tenderness, flavour, juiciness *(and overall liking across the intramuscular fat range) (Data courtesy of Sheep CRC)*

Genetic Correlations				
↑	IMF	↑	tenderness (high correlation, +0.8)	✓
↑	LMY	↓	IMF (high correlation, -0.5)	✗
↑	LMY	↓	tenderness (moderate correlation, -0.4)	✗

Figure 25. Genetic correlations between intramuscular fat, tenderness and lean meat yield

(Data courtesy of Sheep CRC)

Future Carcase and Eating Quality Indexes

Based on consumer eating quality data obtained as part of the Sheep CRC program, it is now possible to calculate an economic value for eating quality, and to include the trait in terminal sire indexes along with growth and carcase traits such as LMY%. The Sheep CRC, Animal Breeding and Genetics Unit (AGBU) and MLA are currently investigating the genetic and economic gains of an index based on these traits, called LMYEQ. The antagonistic relationship between LMY% and eating quality means that achieving simultaneous improvement of the two traits together is difficult but not impossible.

The potential genetic gain of the LMYEQ index over a 10 year period was compared to the current industry Carcase Plus index, based on availability of (1) typical ASBV traits of WWT, PWT, PEMD, PFAT and (2) genomic information from the 50K SNP chips of carcase and eating quality traits in addition to the ASBV traits.

The important results were:

- The current Carcase Plus index predicts substantial improvements in LMY%, but eating quality is predicted to decline.
- The new LMYEQ index will lead to improved eating quality while maintaining LMY% at current levels, provided the breeder is carrying out genomic testing on young rams. Genomic testing provides increased selection accuracy on key carcase and eating quality traits such as intramuscular fat and shear force which allows us to partly overcome the antagonism between LMY% and eating quality.

In comparison with Carcase Plus, the LMYEQ Index will tend to select animals with:

• Similar high growth rate	✓
• Lower eye muscle depth (but still positive)	✓
• Increased fat depth	✗
• Lower response in LMY%	✓
• Positive response in eating quality	✓
• Favourable responses in IMF and shear force	✓

Table 14 shows the potential dollar contribution to economic gain over ten years of selection for each index scenario, assuming that the eating quality breeding objective (LMYEQ) is the most appropriate measure of economic performance. The total dollar gain increases from $13.11 for selection on the CPLUS index with base traits only, to $14.95 for LMYEQ with genomic selection, a 14% improvement.

Table 14. Improvement in contribution to economic gain ($) over ten years (per ewe joined) for Carcase Plus and LMYEQ indexes if economic gain were based on the eating quality breeding objective.

Trait	Carcase Plus (base traits)	Carcase Plus (+genomics)	LMYEQ (+genomics)
PWT	7.85	8.18	9.14
CEMD	5.08	5.42	2.04
CFAT	-0.23	-0.27	-0.28
DRESS	2.43	2.58	1.65
LMY	2.01	2.06	0.35
MSA	-4.02	-4.32	2.05
Total	13.11	13.66	14.95
% improvement	100	104	114

These new indexes will be available on a trial basis in late 2015 and early 2016. They represent a first step in providing breeders with the tools to balance selection on LMY% and eating quality, and show that different levels of emphasis on the two traits are possible. Determining the appropriate balance between the traits is a question to be resolved by industry and ram breeders. The future may involve the development of several indexes for different situations, including markets and breeds.

Demonstrated impact of New ASBVs for LMY and Eating Quality

A recent MLA, Sheep CRC and Sheep Genetics project demonstrated the impact that new ASBVs for LMY and eating quality, particularly intramuscular fat (IMF) and shear force (SF5), will have on lamb production along the supply chain.

Across Australia, at 20 Producer Demonstration Sites (PDS) ewes were inseminated with semen from Poll Dorset, White Suffolk or Merino rams with divergent ASBVs for LMY, IMF and SF5 and managed according to Lifetime Ewe Management recommendations. The lambs were weighed monthly until target slaughter specifications were achieved and were processed through 13 abattoirs for seven lamb supply chains.

In terminal lamb production systems, all ASBVs evaluated increased the correlated trait. A 1% increase in sire LMY ASBV resulted in a 0.31% increase in lamb LMY, as well as a 0.3cm^2 increase in carcase eye muscle area and a 0.2mm decrease in progeny carcase C-fat. LMY ASBV did not have an impact on weaning weight, pre-slaughter weight or live weight gain.

ASBVs for eating quality traits can be used to manage the eating quality of terminal sired lambs. A 1% increase in sire IMF ASBV resulted in a 0.57% increase in lamb IMF and a 1N decrease in sire SF5 ASBV resulted in an increase in loin tenderness in lambs equivalent to a 0.7N decrease in shear force (Figure 30). IMF and SF5 ASBV did not affect weaning weight or pre-slaughter live weight. There were no effects of SF5 ASBV on terminal lamb average daily live weight gain.

There were unfavourable effects of LMY ASBV on tenderness and SF5 ASBV on LMY, such that selection for improved tenderness using SF5 ASBV is likely to decrease LMY in terminal lambs, and selection for improved LMY using LMY ASBV is likely to decrease loin tenderness. Therefore, both LMY and SF5 ASBVs need to be taken into consideration simultaneously in genetic improvement programs in terminal lamb productions systems.

The relationship between ASBVs for LMY and eating quality traits was less clear in Merino production systems. This is most likely due to only three Merino PDS successfully producing lambs for slaughter, with only 24 Merino rams evaluated (compared to 86 terminal rams). Merino LMY ASBV increased Merino lamb LMY but there was no effect of IMF or SF5 ASBV on Merino lamb IMF or tenderness. It is recommended that further Merino PDS are established to demonstrate that these ASBVs can be confidently used in Merino lamb production systems.

This project demonstrated that the newly created ASBVs have a significant linear impact on actual values for their respective traits. Genetic selection for LMY, IMF and SF5 ASBVs will improve productivity, profitability and efficiency of components of the prime lamb industry that use terminal sires, whilst providing consumers with lamb products which give a better and consistent eating experience. Refer to Further Reading section for links to this report.

Chapter 7

Conclusions

This guide to Lean Meat Yield% has set out to identify how the Australian lamb supply chains can achieve higher yielding lamb carcases and more accurate measurement of LMY%.

The economic case demonstrating the value of LMY% across the supply chain was presented. For producers, the increase in on-farm efficiency by using sires with improved feed conversion efficiency is a key profit advantage. For processors, better yielding carcases will improve processing efficiency, reduce wastage and allow new product development. At retail, this will result in markedly improved product presentation for the consumer and improved cutting efficiency of high trim product lines. For consumers, producing higher lean meat yielding carcases with attention to eating quality will ensure that their demand for more lean and less fat on the meat they purchase is met.

This manual has outlined the latest work undertaken by the Sheep CRC, MLA and collaborating seedstock producers, which demonstrates that the current reliance by the Australian Lamb Industry on manual palpation of the GR site to estimate carcase fatness lacks accuracy and is a poor predictor of lean meat yield—indeed no better than carcase weight. Accurate measurement of LMY will allow processors to more precisely value carcases, optimising market-based cutting and de-boning decisions. This will generate the confidence to develop carcase grids and feedback for producers, providing clear market signals for improving LMY%.

Across industry there is a growing recognition of the need to reduce the average fat content on sheep meat carcases. Producers want a good understanding of why some animals yield better than others, and processors seek access to cost-effective, practical and accurate technologies to determine carcase composition, both of which are essential to the meat industry in the future. It is inevitable that there will be wider adoption of procedures that make it possible to differentiate carcases according to quality attributes for particular markets. The challenge for the meat industry is to be able to maximise yields for each of these markets.

Starting with producers, the current Australian Sheep Breeding Values can be used to breed better yielding lambs. Key results from the Sheep CRC Information Nucleus program include:

- PFAT appears to be the most powerful of the ASBVs for increasing LMY% by decreasing whole carcase fatness and increasing muscularity.
- Increasing PWT ASBV increased live weight at slaughter and hot carcase weight, and is therefore a key driver of profitability within prime lamb enterprises.
- The impact of PWT ASBV on LMY% is minimal, with the decreased fatness being largely offset by increased bone, and relatively little change in lean. There was however a significant increase in the distribution of lean to the more valuable saddle region.
- PEMD ASBV has little impact on whole carcase LMY%; however, it does appear to increase the weight of muscle within the higher value loin cuts, in turn increasing the value of the carcase lean. This may imply some level of muscle redistribution to this site.
- Dressing percentage was markedly improved by increasing PEMD ASBV, representing a significant production advantage given that prime lamb producers will be maintaining an animal of similar weight on farm but delivering a markedly larger carcase at slaughter.

This guide also outlined the carcase measurement technologies that are currently being used and also undergoing testing at present. The quantitative technologies include Dual Energy X-Ray Absorptiometry (DEXA) and Computed Tomography (CT) scanning, particularly for the determination of carcase lean meat yield utilising whole carcase scans. Where possible, and economically viable, whole carcase quantitative methodologies will be developed as they are more precise and less prone to bias – measuring "the physical carcase-attribute itself".

Alternatively, the predictive technologies include any that rely on point measurements of particular carcase regions, which are then extrapolated to predict yield or meat quality in the rest of the carcase. This includes tissue depth/area measurement probes for predicting lean meat yield, and probes for measuring meat quality which are used at single sites for estimating traits such as intramuscular fat. The limitation to these predictive technologies is that while the measurement may be precise at the site where the reading is taken, the extrapolation of this measurement to other sites is less precise. Furthermore, it may become biased over time in response to genetic selection at that site.

None-the-less, accurate point measures will still be an improvement from the current industry systems that rely on manual or subjective grading and hence have poor precision and are subject to enormous operator variation. This alone has prevented value based pricing and trading for yield.

In the future, the availability of technologies and data management systems for objective measurement of both LMY% and eating quality will enable a constant stream of reliable data into genetic improvement programs and allow for improved lean meat yield and eating quality breeding values, driving greater rates of genetic gain. The opportunity to capture LMY% information may also enable an accurate cuts based prediction of consumer eating quality and visual appeal, and increase the ability to segment meat cuts, delivering consistent brand integrity to the consumer (i.e. purchaser of the meat tray at retail) increasing retail value.

The consumer eating quality information will be passed across the supply chain, providing (i) producers with information on the eating quality potential of their products, enabling benchmarking of their ability to meet the demands of domestic and international consumers and (ii) retailers/end users with a more informed description of the product they are selling, reflecting its intrinsic value to consumers. This will enable more sophisticated value based marketing. Clear evidence can be found in the beef industry where the Meat Standards Australia grading scheme underpins elite brands, creating an additional $0.80/kg carcase weight back to the producers, thus sharing the increased final value of the products. Signals for price and compliance will encourage the finishing of animals to correct market specifications.

As the relevance of feedback systems increases there will be an increased need for extension activities to drive a stronger link between researchers, processors, farm consultants and producers. This combined focus on LMY and eating quality represents a world first designed to further establish Australia as the international leader for providing affordable, high quality meat products.

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