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Using carcase indicator cuts to predict boning room lean meat yield in lambs

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Abstract

This study aimed to determine whether the weights of particular carcase primal cuts would provide a better prediction accuracy of lean meat yield than utilising Hot Carcase Weight (HCW) and GR tissue depth alone.

156 lambs were boned out using the boning room specifications from Hillsides boning room. Commercial cut weights and Hot Carcase Weight (HCW), GR tissue depth, and a dehydration factor were recorded. Saleable Meat Yield algorithms were derived for the key saleable products produced by the Hillside boning room.

Models utilising the weights of hind-limb components only demonstrated reasonable accuracy with R-squared and RMSE values ranging from 0.31 to 0.42, and 1.77 to 1.58 when incorporating all significant terms. When simplifying these models to only one measurable component for easier implementation into abattoirs, these values changed with R^2 between 0.22 to 0.27 and RMSE 1.86 to 1.80. For comparison, when HCW and GR tissue depth alone were used to determine yield they had an R^2 of 0.11 and RMSE of 1.97.

The predictive models generated by this experiment have a greater accuracy when describing lean meat yield than HCW and GR making them a better descriptor of carcase composition.

Executive summary

The standard procedure used within industry to reflect carcase lean meat yield is based on HCW and GR tissue depth. However, on an individual carcase basis this is not a highly accurate method for determining composition. Therefore this study aimed to determine whether the weights of particular carcase primal cuts would improve the accuracy of yield prediction. It also looked at the feasibility of incorporating these measures into a boning room. Hillside Tender Meats were the cooperating partner for this activity.

156 lambs were boned out using the boning room specifications from Hillsides boning room. Commercial cut weights and Hot Carcase Weight (HCW), GR tissue depth, and a dehydration factor were recorded. Hillside uses four different bone-out methods for the hind-limb within their boning room, thus for each boning method two yield predictive algorithms were derived using a general linear model. These two algorithms included a more complex model using all significant components weighed, as well as a simplified version using the weight of just one cut from the hind-limb along with HCW and GR tissue depth.

Models utilising the weights of hind-limb components only demonstrated reasonable accuracy with R-squared and RMSE values ranging from 0.31 to 0.42, and 1.77 to 1.58 when incorporating all significant terms. When simplifying these models to only one measurable component for easier implementation into abattoirs, these values changed with R^2 between 0.22 to 0.27 and RMSE 1.86 to 1.80. For comparison, when HCW and GR tissue depth alone were used to determine yield they had an R^2 of 0.11 and RMSE of 1.97.

Implementation of the predictive models would require the installation of a weigh table and RFID tag reader in the boning room. A central computer would be required to collate the data and generate saleable meat yield predictions.

The information can be used by the processor to compare producers, breeds, feedlot performance, production methods etc. The saleable meat yield information could also be combined with the HCW and GR grading system already in place, creating a financial incentive for producers to improve the saleable meat yield of their lambs.

The predictive models generated by this experiment have a greater accuracy when describing lean meat yield than HCW and GR making them a better descriptor of carcase composition.

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1 Background

1.1 The Industry

Currently 28% of the world's sheep and lamb exports are produced within Australia. To maintain our competitive edge in the world lamb market Australia needs innovation and improvement in all aspects of production. Currently the industry faces a number of challenges. Labour is difficult to acquire with the mining boom in W.A providing many high paying jobs in rural areas, draining the agricultural sector of labour and the high cattle prices and the lower labour requirements for beef have encouraged producers to invest more in cattle production. The total sheep flock size in Australia is steadily decreasing, now nearing the 100 million mark.

The 2005/6 period had one of the latest starts to the rains in recorded history, and combined with the continued low wool prices it was a tough year for many producers. An important positive contribution to the industry in 2005/6 that helped stabilized income for many sheep producers were the relatively good prices for both lamb and mutton. This highlights how important income from meat has become for Australian sheep farmers. The growing contribution of meat revenue to the sheep industry is also reflected in the record number of merino ewes being joined to terminal sires last year and the merino base in Australia is steadily declining.

The increasing reliance of Australian sheep farmers on the revenue from their meat lambs is causing a shift in the industry. Producers have begun focusing more of their attention on the carcase quality of their lambs. But given the need for transition from a sheep flock focused on wool production to a more meat focused enterprise, this has proven to be a major challenge for the sheep industry. Given that Merinos have been bred for quality wool production, pure merino lambs do not consistently produce good quality prime lamb. For this reason Terminal Sire breeds such as Poll Dorset are used over Merino ewe flocks to generate better quality prime lambs.

In an effort to improve the genetics of Australian lamb, MLA introduced "Lambplan". More recently this system has been amalgamated with various wool genetic improvement databases (ie Merino Select) under a combined MLA and Australian Wool Innovation entity called *Sheep Genetics Australia.* This combined entity introduced ASBV's (Australian Sheep Breeding Values) at the start of last year (2006) and are an improvement on the old EBV's used previously within Lambplan as the breed values are adjusted to be accurate across sheep breeds. An ASBV is a value given to a sire that indicates the ability of the sire to pass the phenotypic traits the sire possesses on to his offspring, i.e. the heritability of traits possessed by the sire. ASBV's can be determined for any trait that exhibits measurable variation between individuals. They are normally calculated for important production traits, for example muscling, growth rate, fat depth etc. In recent years the introduction of ASBV's for stud animals has been a valuable tool in the genetic improvement of the Australian flock.

In spite of the genetic improvements made over the last 10 years, consumers were turning away from lamb due to bad eating experiences particularly the inconsistency in the flavour, texture and tenderness. This highlights the importance of factors other than genetics such as on-farm growth rates and nutrition. In 1995 Allan Jarman recognised the potential that a whole system approach to producing lamb had for improving product quality and consistency and initiated the Q-Lamb alliance.

1.2 Hillside Tender Meats

Hillside tender meats are a state of the art processing facility that is on the forefront of many technological and managerial advances in the industry. It is owned and run by the Trefort family who has over 100 years of experience in the farming industry. Peter Trefort, the owner of the facility has more than 40 years' experience in sheep and cattle production as well as management across the supply chain.

Hillside Tender Meats and 11 lamb producers joined forces to combat the problems in the industry head on and formed the successful alliance Q-Lamb. They have managed to produce a quality product year round labelled Q-Lamb that has succeeded not only in the domestic market but is steadily infiltrating many international markets. The Q Lamb alliance now involves over 200 lamb producers and is well known for its quality and consistency. The alliance has the ability to bring together producers, processors and retailers giving the public a quality branded product that they can rely on. The Q-Lamb alliance has ironed out the peaks and the troughs of the seasonal turn-off and greatly improved the retail presentation and eating quality of the lamb. The consistency of the finished product is mainly attributed to the tailored finishing rations that were introduced for all lambs, based on scientific outcomes of the MLA Sheep meat Eating Quality (SMEQ) program. Even lambs turned-off during spring are given a feed ration for at least two weeks prior to slaughter to ensure the final Q Lamb product has consistent fat and meat colour in the retail cabinet, regardless of its property of origin. WA Q Lamb has a code of practice recommending genetic, management and handling practices and a specification of fat score 2–3, carcase weight of 17 to 23 kg. 98% of lambs processed at Hillside fit the requirements necessary for Q-Lamb.

Hillside is committed to the improvement of the industry and as such is at the forefront of many technological advances. An example is the walk over weighing (WOW) system in place at the small feedlot attached to the abattoir. It automatically weighs the sheep in the feedlot as they travel to the feed troughs. It can also be programmed to draft off animals that have reached a certain weight and need to be separated. Data from the WOW will be downloaded remotely by a CDMA telephone link, directly into a central database. The WOW uses radio frequency identification (RFID) tag technology to identify the individual sheep and this technology has been extended in to the abattoir itself.

A tracking system has been installed into the traditional chain at Hillside Abattoir, Narrogin, WA. An electronic reader located just past the knocking box records the numbers of the sheep as they travel past. Software has been developed to capture the RFID ear tag number and associate it with a similar RFID chip in the gambrel. The animal then can be tracked and individually identified up to the point when the hind quarter is removed from the gambrel and broken down. Six Q lamb producers will be collaborating to demonstrate the benefits of tracking from farm to abattoir. The key areas of interest on-farm are feedlot performance and the monitoring of growth rates between different breeds, genders and birth status (singles v twins). Lambs will be monitored from marking, through the feedlot and at slaughter. The next stage is to improve producer feedback, by making use of individual animal data from on-farm and linking it together with the individual carcase data from the abattoir.

1.3 The project

Calculating lean meat yield on live animals and carcases has been looked at many times in the past. It is a useful final measure of how well the animals performed and represents valuable information at a processing level. Knowing how well animals are performing at slaughter lets Hillside know which producers are managing to improve their flocks, and it can also identify those producers not meeting the same standard that may need assistance. Hillside also has a feedlot facility on site and if every animal has its LMY calculated then different breeds, feeding regimes and source farms can be compared. Eventually the data may be supplied to the stud breeders and even producers wanting to improve the performance of their flocks. This lean meat experiment is different from any other lean meat experiment that has been conducted because it is attempting to put in place a system for linking the data gathered at slaughter with on farm data about the individual animal. Currently feedback on commercial carcase data generated in the abattoir is not provided on an individual animal basis, and thus cannot be linked with on-farm data. The RFID tracking system installed at Hillside's processing facility makes this possible and the data collected, if the project is implemented, so much more valuable. This project will help Q-

Lamb identify which practices produce the best carcases, and which farmers are producing the best animals.

Hillside produces a number of different products from the hind limb of sheep. The range of cuts includes an easy carve leg, a bone in leg; chump off, a boneless lamb leg and a leg; bone in. The central piece of information for the prediction of lean meat yield is the weight of the components of the hind limb, with these components differing from day to day depending upon the bone-out specifications employed for that days product. To improve the accuracy of the predicted value the weight of the hind limb components could be combined with other carcase information such as eye muscle area, GR tissue depth and carcase weight.

One problem associated with estimating lean meat yield is that the cut specifications and level of trimming between different boning rooms may differ. Technologies such as Computer Aided Tomography Scanning (CATscan) can be used to determine carcase composition with a high degree of accuracy. If bone-out studies are carried out at abattoirs in varying locations around Australia in an attempt to establish lean meat yield prediction systems, then technologies such as CATscan may be used to correlate these different algorithms, even though they are derived from operations with differing levels of trim and different cut specifications.

CATscan technology could also be used for periodic calibration of existing lean meat yield algorithms. Boning out a large number of animals is time consuming and expensive and the product left at the end has limited resale potential. If the CAT scan could be used to calculate lean meat yield then only the relevant cuts of the hind quarter produced in the boning room would need to be weighed thus eliminating a lengthy bone out experiment. This means that every 1 to 2 years there could be a CAT scan study to check the accuracy of the algorithm – an important contingency in an industry that is making such rapid genetic gain. There is even the possibility that at some point in the future a CAT scanner may be installed in a processing plant and every animal would be CATscanned and lean meat yield calculated directly from the images.

2 Project objectives

The aim of this project is to generate a lean meat yield prediction algorithm capable of predicting yield utilising basic carcase information collected on-line at the abattoir, as well as the weights of the muscle bone and fat components of the hind limb collected in the boning room on a customised set of scales. This prediction algorithm will be correlated with other algorithms using CATscan determined carcase composition.

3 Methodology - Section

3.1 Methodology background

The purpose of this experiment was to formulate an algorithm that predicted the saleable meat yield of a carcase from the weight of a specific cut from the hind quarter. The project was aimed at an industry level so instead of generating data describing a carefully specified lean meat yield, as generated by SASTECH for their VIAscan bone-outs, the saleable meat yield which was relevant to the trimming specifications of Hillside Meats was calculated. The animals chosen to participate in the experiment were dissected to saleable meat, fat trim, meat trim and bone, with special attention paid to the hind quarter which forms the basis of the algorithm. From the data generated several algorithms were created that allow the prediction of lean meat yield from single or multiple carcase indicator cuts.

Saleable meat yield is defined as the weight of saleable meat produced from a carcase, to a set of specifications. This is expressed as a percentage of the cold standard carcase weight. The specifications may include a layer of fat to a set depth and/or include some bone. In this experiment the specifications for saleable meat yield includes fat to the depth specified by the hillside regulations and no bone.

3.2 The animals

Figure 3.1. Q-lamb carcases

156 lambs were selected for bone out. All animals used in the experiment had been classified as Q-Lamb. The W.A. Q-Lamb code of practice (Appendix 1) contains the ideal range of weights and fat scores for Q-Lamb animals. This code also includes production guide lines, such as feed composition, that must be followed for the animals to be classified Q-Lamb. In order for the algorithm to confidently predict the saleable meat yield of animals processed at Hillside, the carcases used in the experiment needed to represent the range of animals that fitted within the specifications of Q-lamb – this data set is the best representation of this range that could be achieved during the time frame of the project.

Approximately 15 lambs per week were acquired from Hillside's regular intake of stock. The preliminary selection of potential subjects occurred the day before the animals were slaughtered. The likely-hood of the animals within the flocks being suitable for the bone-out were assessed, and the animals within the flock that were likely to produce carcases with a desirable range of weights and fat scores were identified for closer inspection after slaughter. If on farm information about the flock was potentially available then those animals were preferentially selected, provided they were the correct weight and fat score.

The information collected from the abattoir about the animals that were used in the experiment was;

- Carcase weight
- Fat score
- Breed
- Sex

Breed and sex is not part of the information recorded for each animal slaughtered at hillside, and had to be collected manually after slaughter. On some days this information proved to be difficult to source and thus not all of the carcases had this data recorded. The on farm information that was collected when it was available was sire name and number, to determine the, Muscling ASBV, Fat ASBV and the Growth ASBV for the animal and the nutritional history.

3.3 Experimental protocol

The bone-out was carried out over a period of 10 weeks. Each week the 15 carcases selected were slaughtered at Hillside abattoir on Tuesday, trucked to Murdoch University on Wednesday morning and CATscanned on Wednesday afternoon. They were then trucked (in a refrigerated container) to the commercial boning room on Thursday and then boned out and weighed on Friday afternoon. In some cases slaughters were carried out on Mondays, and bone outs done on Thursdays, however for all prediction algorithms HCW at bone out and dehydration has been included (irrespective of significance level) to take account of differing levels of carcase dehydration.

3.3.1 CAT Scanning

Figure 3.2. CAT scanning

CAT scanning was carried out at Murdoch University. All carcases were unloaded into a 5˚C chiller and prior to CAT scanning were weighed, and the length measured. Weights collected provided an accurate weight for CAT scanning data to be correlated with, as well as providing an estimation of the carcase dehydration taking place between CAT scanning and slaughter.

To ensure that the entire animal fitted within the field of the CAT scanner the carcases were bent over at the mid section, with the fold in the lumbar region of the spine as shown in Figure 2.2. The CAT scanner operated with 5mm slice widths, with each slice taken 4cm apart.

3.3.2 Bone-out

The carcases were boned out by a commercial whole sale butchering company. The same 3 boners were used across the entire data collection period, with each boner specialising in one portion of the carcase to maximise the consistency of trimming for each cut. For a list of the bone-out specifications please refer to Appendix 3. At the points indicated in Appendix 3 the saleable meat, bone and fat were weighed. The weigh table was wirelessly connected to a tough book laptop computer which automatically downloaded the data into an excel file. The scale had a minimum weight of .1kg and a maximum weight of 15kg with an error of .005kg.

Hillside produces many different products from lamb and they each require different bone-out procedures. The different bone-out protocols in place at Hillside created the need for flexibility in the data required to predict lean meat yield. To achieve this flexibility special attention was paid to the hind limb with specific weights of the hock bone, tibia minus hock, and other hind limb bones recorded, meat and fat trim recorded, and the weight of the chump, round, and remaining leg muscles recorded.

The animals were weighed prior to the bone out to compensate for the dehydration of the carcase. Determination of the eye muscle area was achieved by taking photos of the cranial and caudal aspect of the right side short loin and using an image analysis program to calculate the area. Samples of the flap muscle were collected so the chemical lean for this component could be calculated for each animal. Samples of the longissimus dorsi were also taken to allow for the possibility of future chemical analyses of this muscle to correlate with CATscan images. Rack length was also recorded to allow for the generation of an algorithm predicting rack length from total carcase length.

3.4 Statistical analysis

Hillside has 4 different methods of boning-out the hindlimb that they use regulary for Q-lamb. Each bone-out method generates different hindlimb components that can be utilised for the prediction of saleable meat yield, hence a different prediction model was formulated for each bone out method providing Hillside with the flexibility to determine yield no matter what their boning specification are on that day. The algorithms were generated for the following bone out methods:

1. Easy Carve Leg
2. Bone in Leg, chump off
3. Boneless Lamb Leg
4. Bone in Whole Leg

General linear models (SAS) were used to generate the prediction algorithms. Multiple terms were tested within each model (as demonstrated in Table 2) and non-significant terms (P>0.1) sequentially deleted. Algorithm coefficients, F-values, R-squared (R^2), and Root Mean Square Error (RMSE) are presented as indicators of predictive power and accuracy of models. In all cases Hot Standard Carcase Weight (HCW), GR tissue depth, and Dehydration at boning (HCW-Cold Carcase Weight at boning) were retained in the models irrespective of significance.
This stepwise regression process was then repeated until each algorithm contained only 1 indicator cut as well as HCW, GR tissue depth, and Dehydration.

The data set was then partitioned according to breed, sex, weight, and fat score, and the accuracy of the prediction equations were investigated by running the prediction models for each group and comparing the results.

To assess the increased value of an extra rib in the rack the total weight of the rack was divided by the number of ribs. That number was assumed to represent the combined weight of the bone muscle and fat associated with one rib, and was added to the total weight of the rack to estimate the effect an extra rib would have on rack weight. To determine the dollar value of the extra rib the price per kilo for the rack was multiplied by the weight of an extra rib with the weight lost from the short loin multiplied by the short loin price per kilo subtracted from the increased revenue from the rack.

4 Results and discussion

4.1 Results

4.1.1 Animal information

156 sheep were used in this experiment with 72 merinos and 84 mixed breed lambs. Of the mixed breeds 9 were suffolk X texel X merino, 6 were suffolk X merino, 7 were dorset X merino, three were South African Meat Merino (SAMM) X merino, and the rest were undefined. 42 lambs were female and 81 male. 34 animals did not have sex recorded. Table 4.1 summarises the fat scores and weights of the animals. The distribution of animals across the weight x fat matrix was partially biased by availability, with a higher proportion of the animals in the middle of the weight and fat ranges.

Table 4.1: Carcase weight and fat matrix. Values represent the number of lambs in each cell.

	Cross Bred			Merino		
HCW (kg)	Fat Score			Fat Score		
	2	3	high3	2	3	high3
17	1	1	2	1		1
18	4	4	1	3	1	
19	3	5	3	6	1	
20	3	7	1	4	4	
21	0	6	4	8	5	1
22	5	2	4	9	7	
23	4		4	4	2	1
24	4	2	2	3	1	1
25	2	4	1		2	1
26	3	1		1		1
27	1			2		
28	1					

The mean±S.E. HCW and GR tissue depth for the carcases was 21.4±0.2kg, and 11±0.19mm, with the carcase fat and weight range represented in Table 4.1. The full breakdown of the carcase with the components weighed is presented in Figure 4.1.

The mean and standard deviation for saleable meat yield percentage was 65.53±0.10%.

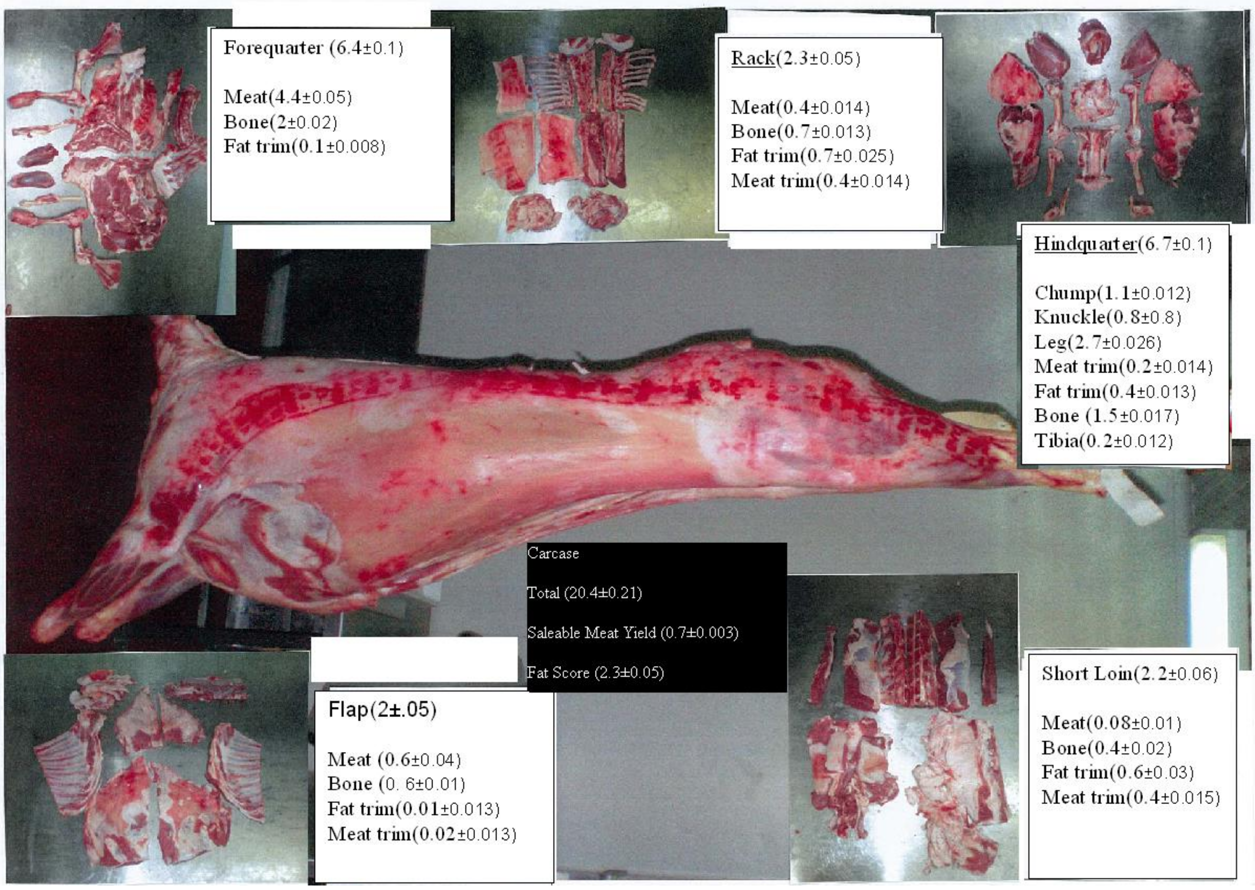


Figure 4.1. A visual representation of the carcase breakdown with their mean±S.E component weights (kg).

4.1.2 Predictive models

Hillside utilises 4 different bone-out procedures for the hindlimb, depending upon what market is targeted for that product. Lean meat yield prediction algorithms have been generated for each of these, incorporating a range of different hindlimb components (ie muscle, bone and fat), as well as components of the rack. The terms tested and the algorithms derived within each are presented in tables 4.2 and 4.3 below. The easy carve leg algorithm utilises 12 less animals, as this data was not collected in the first bone-out week. Other variation in total animals used is due to exclusion of data due to outlying values.

Table 4.2: An outline of the data points used in all models predicting saleable meat yield
✓, data available; ✓✓, data significant; ×, data not available; ❍, data used in simplified predictive model
Cranial and Caudal EMA= the surface area of the cranial and caudal aspect of the eye muscle of the short loin

	easy carve leg	**bone in leg**	**boneless lamb leg**	**bone in leg, chump off**	**Rack**	**Rack and leg**
Hot carcase weight	❍✓✓	❍✓✓	❍✓✓	❍✓✓	❍✓✓	❍✓✓
Fat Score	✓	✓	✓	✓	✓✓	✓
GR	❍✓✓	❍✓✓	❍✓✓	❍✓✓	❍✓✓	❍✓✓
Grower	✓	✓	✓	✓	✓	✓
Breed	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Sex	✓	✓	✓	✓	✓	✓
Carcase Length	✓✓	✓✓	✓	✓✓	✓	✓✓
Dehydration	❍✓✓	❍✓✓	❍✓✓	❍✓✓	❍✓✓	❍✓✓
leg bone weight	×	×	✓✓	×	×	✓
Tibia weight	×	×	×	×	×	✓
fat trim from leg	✓✓	×	×	✓	×	✓✓
meat trim from leg	✓✓	×	×		×	✓✓
Boneless chump weight	✓	×	×	✓	×	✓
Weight of knuckle	✓✓	×	×	✓	×	✓✓
Total leg weight	✓	❍✓✓	✓✓	❍✓✓	×	✓
Saleable meat yield of the leg	×	×	✓	×	×	✓
Boneless leg weight	×	×	❍✓✓	×	×	✓
easy carve leg weight	❍✓✓	×	×	×	×	❍✓✓
Cranial EMA	✓✓	✓✓	✓	✓✓	❍✓✓	✓✓
Caudal EMA	✓	✓	✓	✓	✓	✓
Rack meat trim	×	×	×	×	✓	✓✓
Rack meat	×	×	×	×	✓	✓✓
Total rack weight	×	×	×	×	✓	✓✓
Rack bone	×	×	×	×	✓✓	✓
Rack fat trim	×	×	×	×	✓	✓

Table 4.3: Carcase lean meat yield (%) prediction models based upon the various hindlimb products boned out at Hillside Meats. Values are presented for co-efficients±S.E., degrees of freedom, and F-values for each term within the model, as well as R^2 and RMSE of the total model.

Current Practice	HCW, GR (0.11, 1.97) $^{\psi}$			HCW, GR, EMA (0.21, 1.87) $^{\psi}$		
	NDF/DDF	F-Value	Co-efficient ± SE	NDF/DDF	F-Value	Co-efficient ± SE
Intercept	-	-	61.9±1.46	-	-	60.4±1.44
HCW (kg)	1/146	15.35***	0.27±0.070	1/142	4.35**	0.15±0.072
GR (mm)	1/146	8.15***	-0.21±0.075	1/142	5.77**	-0.17±0.071
Eye Muscle Area (mm^2)				1/142	17.35***	0.003±0.0006
Easy Carve Leg	All Terms (0.42, 1.58) $^{\psi}$			Simplified (0.27, 1.80) $^{\psi}$		
	NDF/DDF	F-Value	Co-efficient ± SE	NDF/DDF	F-Value	Co-efficient ± SE
Intercept	-	-	59.8±1.281	-	-	60.3±1.44
HCW	1/134	16.8***	-0.64±0.155	1/135	6.61**	-0.38±0.149
GR	1/134	0.63	-0.05±0.066	1/135	4.12**	-0.14±0.072
Dehydration	1/134	5.53	1.35±0.575	1/135	4.83**	1.39±0.634
Leg meat trim	1/134	41.2***	9.55±1.488	-	-	-
Leg Fat trim	1/134	0.05	-0.34±1.571	-	-	-
Easy carve weight	1/134	38.23***	5.57±0.900	1/135	72.6***	4.59±0.972
Bone in Leg	All Terms (0.31, 1.77) $^{\psi}$			Simplified (0.22,1.86) $^{\psi}$		
	NDF/DDF	F-Value	Co-efficient ± SE	NDF/DDF	F-Value	Co-efficient ± SE
Intercept	-	-	60.85±1.405	-	-	60.16±1.473
HCW	1/152	6.24**	-0.48±0.191	1/152	4.14**	-0.14±0.07
GR	1/152	6.78**	-0.18±0.067	1/152	4.94**	-0.45±0.201
Dehydration	1/152	8.62***	1.76±0.598	1/152	4.96**	1.39±0.625
Merino adjustment	1/152	17.91***	-1.24±0.292	-	-	-
Total Leg Weight	1/152	16.3***	2.36±0.584	1/152	13.43***	2.26±0.616
Boneless lamb leg	All Significant Terms (0.41, 1.63) $^{\psi}$			Simplified (0.36, 1.70) $^{\psi}$		
	NDF/DDF	F-Value	Co-efficient ± SE	NDF/DDF	F-Value	Co-efficient ± SE
Intercept	-	-	61.93±1.221	-	-	61.26±1.259
HCW	1/152	21.43***	-0.72±0.156	1/152	23.09***	-0.78±0.162
GR	1/152	11.17***	-0.20±0.06	1/152	7.59***	-0.17±0.062
Dehydration	1/152	6.91***	1.45±0.551	1/152	4.1**	1.15±0.568
Breed	1/152	13.82***	-1.00±0.271	-	-	-
Boneless LEG	1/152	45.22***	3.81±0.567	1/152	46.85***	4.03±0.588
Shortloin	All Significant Terms (0.46, 1.56) $^{\psi}$			Simplified (0.34,1.71) $^{\psi}$		
	NDF/DDF	F-Value	Co-efficient ± SE	NDF/DDF	F-Value	Co-efficient ± SE
Intercept	-	-	61.17±1.214	-	-	62.25±1.284
HCW	1/146	3.38*	-0.21±0.116	1/146	8.02***	-0.28±0.099
GR	1/146	2.14	0.1±0.069	1/146	0.8	-0.06±0.068
dehydration	1/146	20.54***	2.48±0.547	1/146	12.03***	2.058±0.593
SLmeat	1/146	22.3***	8.37±1.773	1/146	43.09***	11.50±1.753
SLmeat_trim	1/146	14.12***	5.31±1.414	-	-	-
SLfat_trim	1/146	9.98***	-2.71±0.857	-	-	-

Rack	All Significant Terms (0.51,1.48)[Ψ]			Simplified (0.21,1.85)[Ψ]		
	NDF/DDF	F-Value	Co-efficient ± SE	NDF/DDF	F-Value	Co-efficient ± SE
Intercept	-	-	60.04±1.232	-	-	62.07±1.401
HCW	1/144	7.93***	0.269±0.095	1/144	22.98***	0.511±0.106
GR	1/144	0.40	0.043±0.068	1/144	3.25*	-0.13±0.072
dehydration	1/144	11.64***	1.774±0.520	1/144	4.61**	1.372±0.639
Wt_R_No_Tray	1/144	2.58	-1.54±0.960	1/144	13.55***	-2.60±0.706
Rfat_trim	1/144	5.46**	-2.93±1.253	-	-	-
Rmeat_trim	1/144	14.6***	6.113±1.600	-	-	-
CrEMA (mm^2)	1/144	13.81***	0.002±0.0005	-	-	-
Breed	1/144	10.65***	-0.89±0.275	-	-	-

Sheep CRC Algorithm	All Significant Terms (0.61,1.33)[Ψ]		
	NDF/DDF	F-Value	Co-efficient ± SE
Intercept	-	-	60.98±1.136
HCW	1/141	0.51	0.09±0.137
GR	1/141	3.95**	0.12±0.061
dehydration	1/141	11.66***	1.60±0.471
SLfat_trim	1/141	53.99***	-6.40±0.871
SLmeat	1/141	17.02***	6.76±1.639
LRound	1/141	3.47*	3.66±1.965
LBone	1/141	10.69***	-2.32±0.709

[Ψ] Values are (R-squared and RMSE)
*= P<.1 **=P<.05 ***=P<.01,
CrEMA = the area of the cranial aspect of the short loin eye muscle.

Most abattoirs in Australia offer their suppliers a grid based on HCW and GR, these being the only indicators of yield. If saleable meat yield was predicted from HCW and GR alone using the Hillside bone-out specifications then the R^2 would be 0.11 and the RMSE 1.97.

Utilising hindlimb components only, the R-squared and RMSE values ranged from 0.31 to 0.42, and 1.77 to 1.58 when incorporating all significant terms. When simplifying this model to only one measurable component for easier implementation into abattoirs, these values changed between R^2 0.22 to 0.27 and RMSE 1.86 to 1.80.

The predictive models based on the short loin alone had R^2 of 0.46 and 0.34 and RMSE of 1.56 and 1.71. When a combination of short loin and leg components are included in the model, copying the combination of carcase components utilised in the Sheep CRC yield prediction algorithm, the R-squared increased to 0.61, and the RMSE decreased to 1.33.

The predictive performance of these models is visually demonstrated in figures 4.2 – 4.7 below.

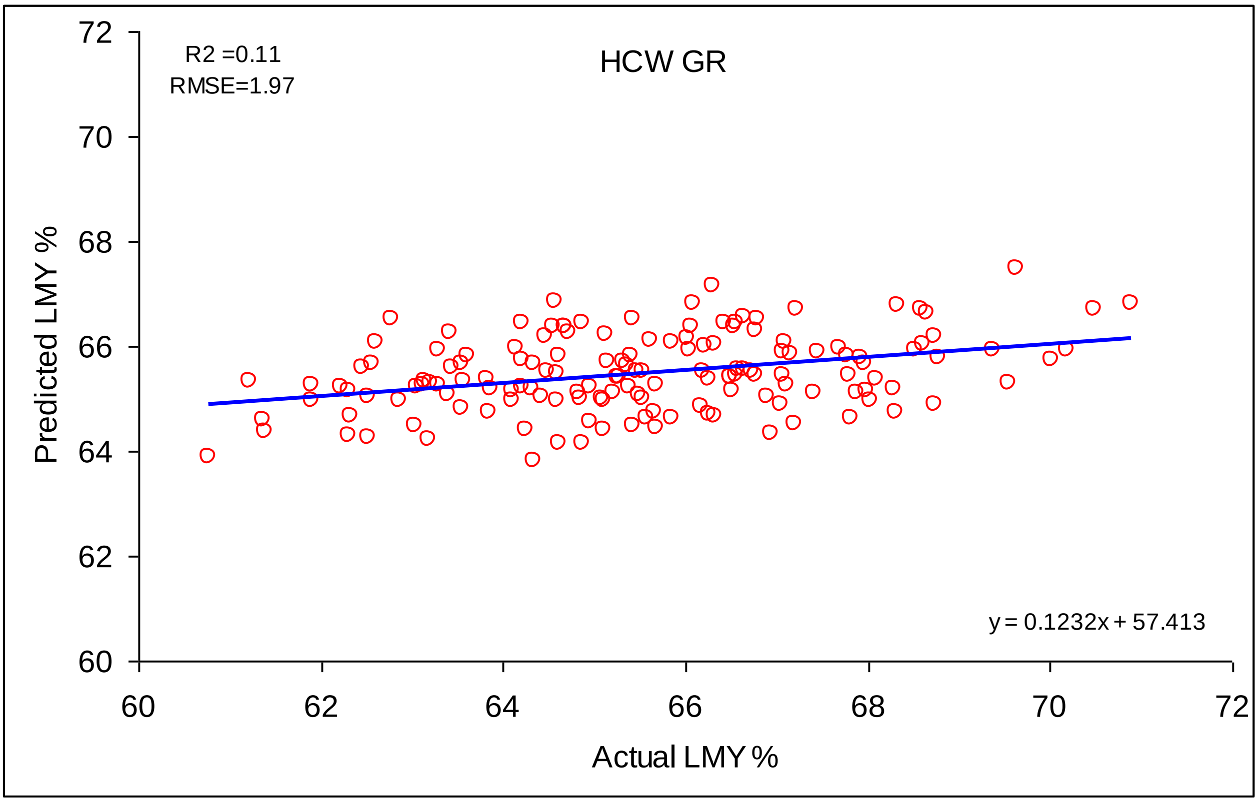


Figure 4.2. Predicted versus actual lean meat yield % for the predictive model consisting of HCW and GR tissue depth.

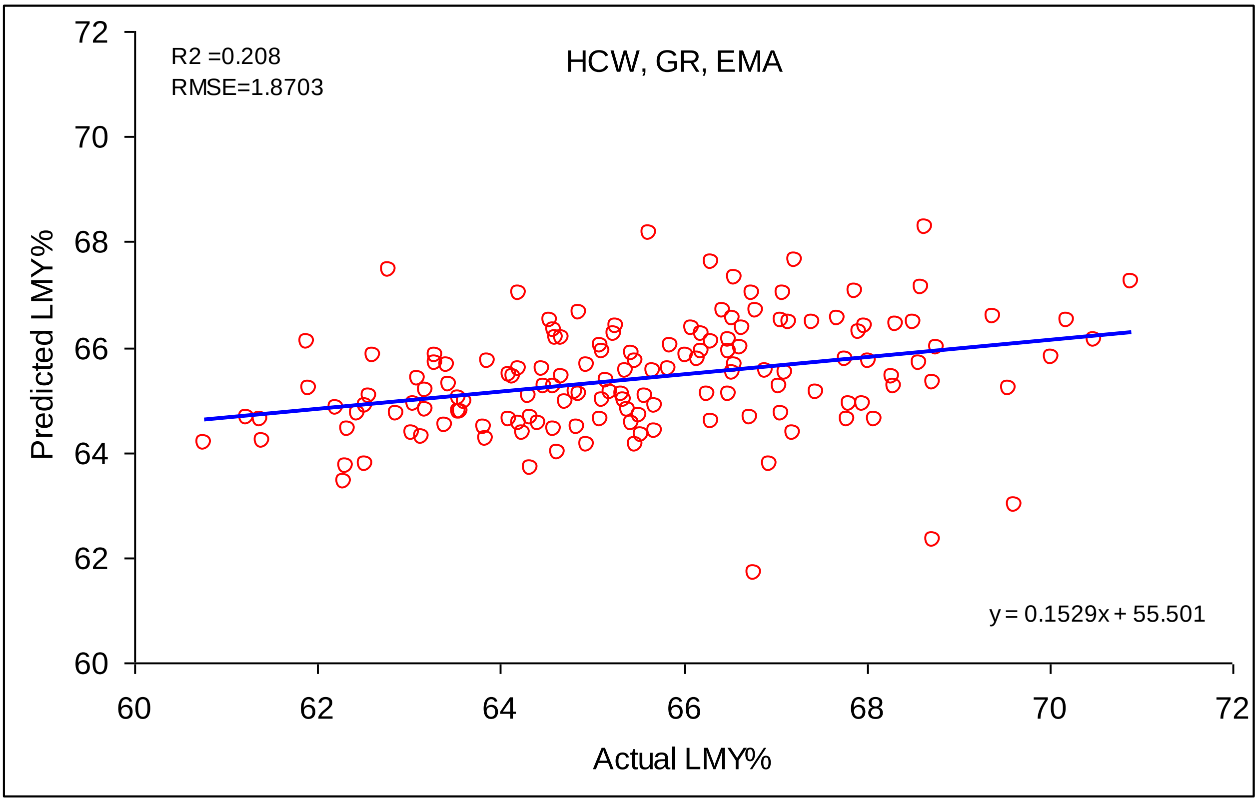


Figure 4.3. Predicted versus actual lean meat yield % for the predictive model consisting of HCW, GR tissue depth and EMA.

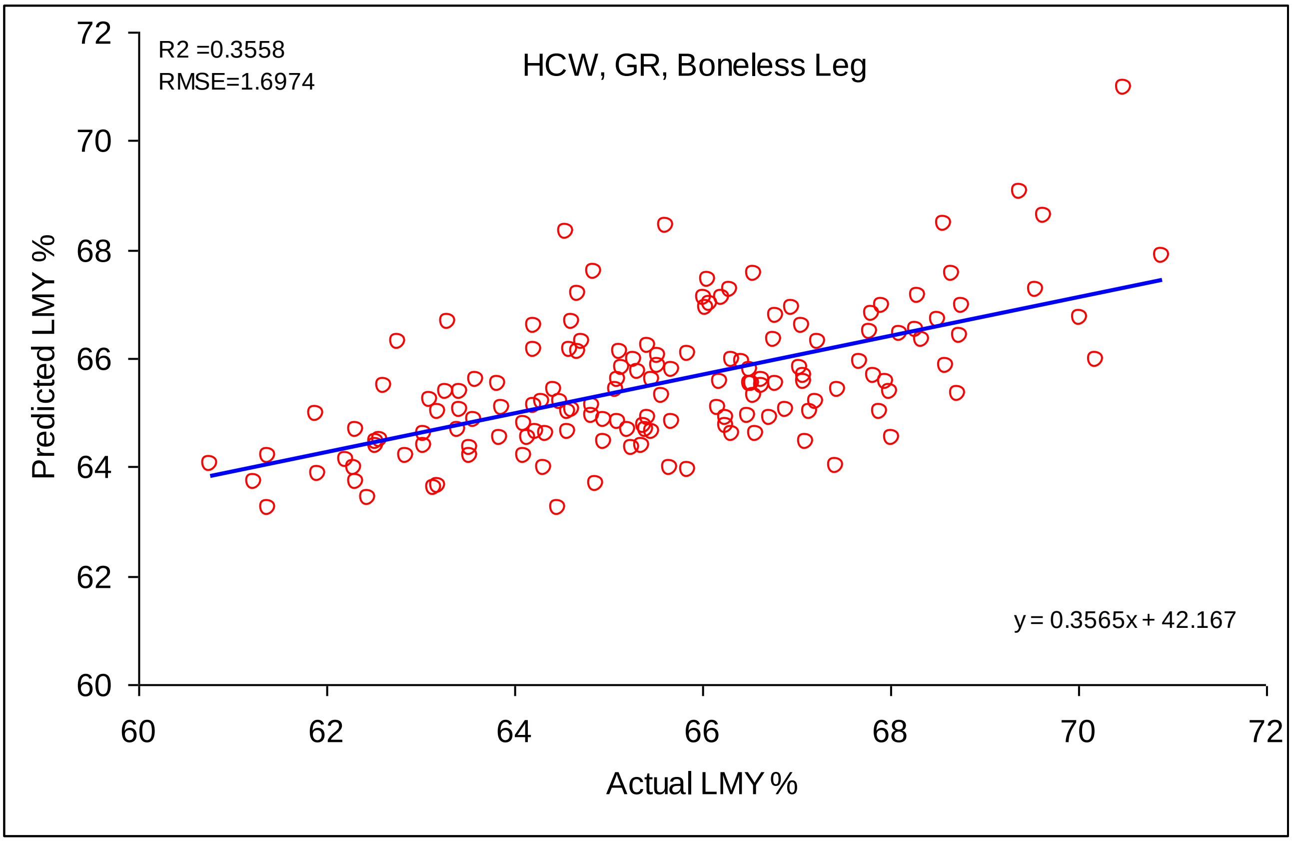


Figure 4.4. Predicted versus actual lean meat yield % for the predictive model consisting of HCW, GR tissue depth, dehydration, and boneless leg weight.

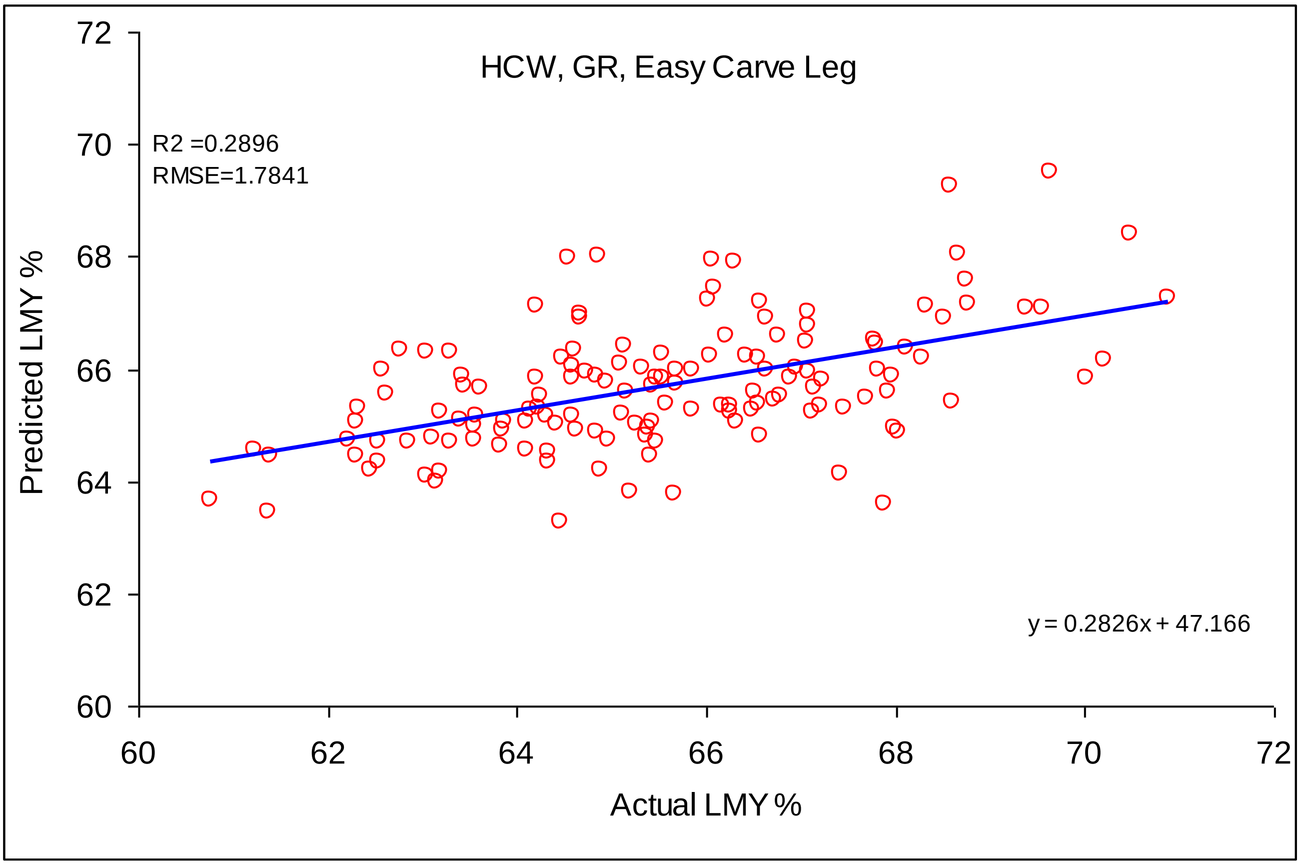


Figure 4.5. Predicted versus actual lean meat yield % for the predictive model consisting of HCW, GR tissue depth, dehydration, and easycarve leg weight.

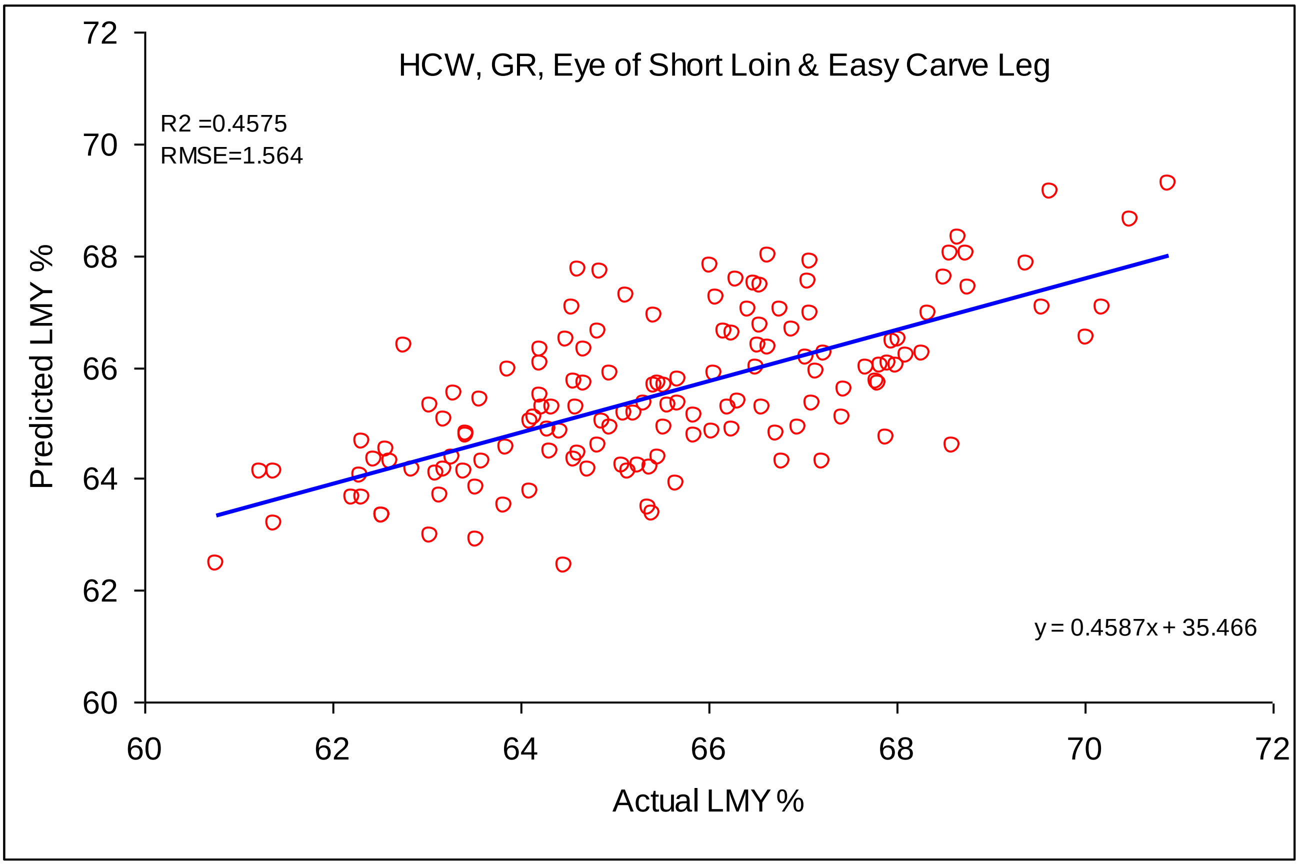


Figure 4.6. Predicted versus actual lean meat yield % for the predictive model consisting of HCW, GR tissue depth, dehydration, eye of shortloin weight and easycarve leg weight.

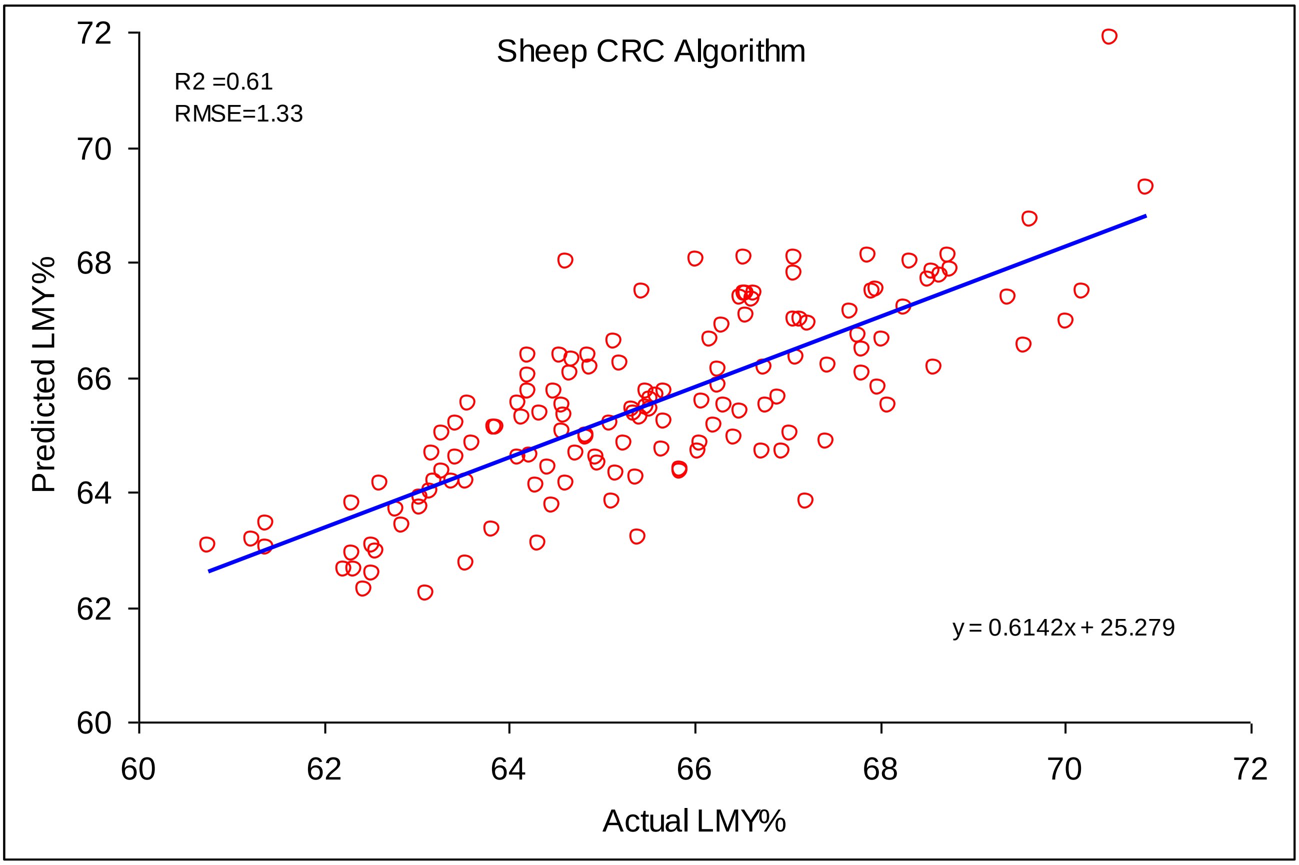


Figure 4.7. Predicted versus actual lean meat yield % for the predictive model consisting of HCW, GR tissue depth, dehydration, eye of shortloin weight, shortloin total fat weight, round weight, and total leg bone weight. This is the same combination of carcase components utilised in the Sheep CRC yield prediction algorithm.

4.1.3 Model robustness

The prediction for saleable meat yield within subsections of the data set varied from the actual by between 0 –2 saleable meat yield percentage units. The greatest inaccuracy was evident in weeks two, three and six, with an error of 2%. The difference between bone-out weeks in most cases can be viewed as a proxy for different genetic lines of animals, but is confounded by environmental impacts such as nutritional history and therefore cannot be entirely discounted as genetic effects.

Table 4.3. Actual saleable meat yield of carcase compared with the predicted saleable meat yield as determined for the boneless leg (all significant terms included) yield prediction model within subsets of the total data.

Data Subset	Predicted Saleable Meat Yield	Actual Saleable Meat Yield	Difference between actual and predicted saleable meat yield
	Mean ± SE	Mean ± SE	
All data (N=156)	65.53±0.16	65.53±0.10	0
Male(N=81)	66.07±0.19	65.73±0.13	-0.34
Female(N=41)	65.09±0.37	65.25±0.16	0.16
HCW < 20kg (N=48)	64.51±0.30	64.78±0.10	0.27
20kg < HCW < 23kg(N=69)	65.83±0.23	65.48±0.13	-0.35
HCW > 23kg (N=39)	66.12±0.31	66.33±0.23	0.21
Fat score 2 (N=72)	65.71±0.25	65.87±0.16	0.16
Fat score 3(N=56)	65.57±0.28	65.32±0.14	-0.25
Fat score high 3 (N=28)	64.96±0.34	65.06±0.18	0.10
Xbreed (N=84)	65.95±0.22	65.50±0.13	-0.45
Merino(N=72)	65.04±0.24	65.55±0.15	0.51
Week 1(N=12)	65.69±0.65	65.94±0.35	0.25
Week 2(N=15)	67.16±0.46	65.39±0.37	-1.77
Week 3(N=14)	67.15±0.41	65.43±0.24	-1.72
Week 4(N=15)	65.14±0.51	64.85±0.18	-0.29
Week 5(N=15)	63.34±0.32	64.27±0.14	0.94
Week 6(N=15)	63.76±0.15	65.44±0.20	1.68
Week 7(N=15)	66.37±0.52	66.31±0.44	-0.06
Week 8(N=15)	67.05±0.40	66.06±0.25	-0.99
Week 9(N=14)	66.30±0.31	66.02±0.27	-0.28
Week 10(N=11)	64.90±0.44	65.31±0.24	0.41
Week 11(N=15)	65.09±0.27	65.51±0.33	0.42

HCW = hot standard carcase weight

Xbreed = Merino crossed with a terminal sire sheep breed.

4.1.4 The effect of increasing rib number on rack size

The number of ribs on a sheep can vary from 12 to 14. A sheep with 13 ribs has 0.3kg more saleable rack than a sheep with 12 ribs. A sheep with 14 ribs has proportionally 0.3kg more saleable rack than a sheep with 13 ribs. If there was a consistent supply of animals with 14 ribs, a 10 rib rack could be created which would weigh on average 0.3kg more than a 9 rib rack.

4.1.5 CAT scanning

CAT scan images have been collected for each animal and will be used to calibrate this yield prediction system with prediction systems at other plants once this data becomes available.

4.2 Discussion

4.2.1 Predictive models

There were two predictive models formulated for every hindlimb bone-out method. One included all the significant terms in the predictive equation and the other was a simplified version containing HCW, GR, carcase dehydration up to the point of bone-out and one measurement from the hindlimb. The simplest models were formulated to provide Hillside with algorithms that required the least amount of data input and would be relatively easy to incorporate into the regular boning room operations. Thus there would be a trade-off between accuracy of the more complex models, and ease of integration for the more simplistic models. Either model represents an improvement on estimating yield with the industry standard of HCW and GR. The ranges of R^2 and RMSE in the models are comparable to a recent study conducted using VIAscan to estimate lean meat yield in Merino lambs which achieved an R^2 of 0.47 and a RMSE of 2.20.

Although the bone-out methodology may appear crude when considered superficially, the accuracy achieved with the results suggests that very consistent data was collected. The accuracy of the data may have been due to the minimal amount of trim required for the Q-lamb product, with the most trim removed from the shortloin and the rack portions of the carcase. The minimal amount of trim decreases the amount of operator (boner) error that is incurred. Also the effect of the operator on the data was minimised by ensuring that each of the three boners only boned the same particular section of each carcase for the entire experiment, thus making the data collected less variable and therefore the predictive power of the yield models more accurate.

The information gathered by implementing predictive models will allow Hillside to test and compare the performance of individual producers and could possibly be incorporated into the financial incentive system running at Hillside which is currently based on HCW and GR. The algorithms can also provide information to aid in the evaluation of production methods, which can be then passed on to the producers in the form of production guidelines. The relative performance of specific breeds and feedlot performance of different groups of animals can be assessed to a greater extent with these algorithms allowing hillside to preferentially purchase stock into their feedlot that was likely to produce greater saleable meat yields.

4.2.2 Accuracy

In order to maintain accuracy over time the predictive algorithms need to be correlated periodically with repeated bone-out trials. The CAT scan images recorded in this study have the potential to provide a means of accurate calibration, with the CAT scan images of carcases replacing physical bone-outs of carcases, thus representing an alternative means of maintaining the accuracy of the predictive models into the future.

4.2.3 Model robustness

The variation between the predicted and the actual saleable lean meat yields was generally between 0, and at worst 0.02. Baring the last figure, this is quite a small difference and gives a good demonstration of the transportability and high degree of accuracy achieved by the predictive models. The accuracies of the sub-groups did not differ significantly from each other indicating that the predictive algorithm retained similar accuracy for all the sub-groups of lambs. To properly assess the ability of the predictive models to retain its accuracy over variant lambs more animals must be included into the data set, especially in the higher fat ranges, and the higher weight ranges for merinos. The greatest inaccuracy was evident within weeks two, three and six but even within these group the difference between the means was only 0.02. Each week also exhibited a difference, and can be viewed as a proxy for different genetic lines of animals, although this cannot be seen as a purely genetic effect as it is confounded by environmental impacts such as nutrition.

4.2.4 Flexibility of the data

Hillside supply a range of different markets that each require different products, and as such we have generated predictive models to fit the particular operation within the boning room on any particular day. This gives hillside the ability to use the predictive models for lean meat yield without being restricted to a single bone-out method. The accuracies of the predictive algorithms differ, depending on the bone-out method. The most accurate predictive model was the model using data from the easy carve leg.

4.2.5 Implementation

To integrate the data collection for the predictive algorithms into the boning room Hillside would require some additional weigh points. The include:

1. Bone-out cold carcase weight - an additional weigh point and RFID tag reader, located at the entry point to the boning room, would allow the collection of boning room cold carcase weight, enabling calculation of dehydration (taken as the difference from the recorded HCW).
2. Bone-out leg weight – this may require a customised bone-out weigh-table with a knee/foot operated weight recording system, positioned where the boner breaks down the hind limb. Alternatively, a bar coding system for each leg could be employed enabling individual tracking of each leg and weight recording at a point further down the chain. This would also require a fourth gambrel RFID tag reader to be installed in the boning room at the point where the hindlimb is removed from the gambrel.
3. Rack or shortloin – for increased accuracy components of the rack or shortloin could be weighed, however this would require the same additional infrastructure as needed for the leg weight.

The new gambrel RFID tag reader links the specific cut weights collected on the boning room floor to the rest of the information collected about the carcase. The weights collected can be transmitted to a central computer system which would process the data and apply the appropriate predictive equation for that bone-out method and generate a predicted saleable meat yield. This information processing system could be designed and implemented in a fashion that integrates with the information technology system already in place at Hillside – provided by SASTEK.

4.2.6 Conclusion

The accuracy achieved by the predictive models generated by this experiment was better than the predicted accuracy outlined in the project brief, Appendix 4. The predictive models, including all significant terms achieved accuracies comparable (or better) to those of VIAscan. This means that these prediction algorithms may be a viable alternative to installing VIAscan technology in processing plants, although implementation at the operational level in the boning room is likely to

be problematic. The best prediction model utilising weights solely from the hind limb achieved an R-squared and a RMSE of 0.42, 1.58, this prediction equation based on the boneless lamb leg method of breaking down the hindlimb. The most accurate model which included only one weight from the hindlimb was also from the boneless lamb leg bone-out method and achieved an R-squared and a RMSE of 0.36, and 1.70. Both of these models are far more accurate than the predictive power of HCW and GR which, using data collected from this experiment achieved an R-squared of 0.11 and a RMSE of 1.97. The R-squared and the RMSE comparisons between HCW and GR and the predictive models indicate the vast improvement on the ability for boning room information to describe carcase quality.
Predicting the saleable meat yield on a large number of carcases processed at Hillside would provide valuable information about the quality of different producers, breeds and production methods. It would enable Hillside to more effectively assess individual producers and the quality of the lambs processed at Hillside. The saleable meat yield information that can be generated from this experiment provides a much better description of carcase quality than any other method currently available at hillside. Increased knowledge about carcase quality increases the ability of Hillside to provide feed back to producers on what quality is preferred and what methods to achieve better lamb quality.

5 Success in achieving objectives

1. To generate a lamb and hogget bone-out data set using cuts specific to the Hillside abattoir operation. This has been successfully completed.
2. To generate a prediction algorithm for estimating lean meat yield by using cuts specific to the Hillside abattoir operation. This has been completed, and multiple prediction algorithms are available.
3. Use CATscan technology as a calibration point with other yield prediction algorithms. This component will be formally carried out when the CATscan data sets become available from the Sheep CRC kills and following similar work to this at Jacksons (Tamworth, NSW).

6 Impact on meat and livestock industry – Now and in five years time - Section

With the accuracy of the more complex predictive models included in this report (see the results section) it seems possible that other processing plants in Australia could build their own algorithms, based upon their own specific procedures (particularly with respect to level of trim) to provide a nation-wide yield prediction capability spread across a wide range of processors, farming conditions and producers. A nation wide capability for yield prediction could provide the data flow required for the generation of a yield genetic indece (Australian Sheep Breeding Value). The ASBV would utilise the predicted saleable meat yield from progeny of sires from all over Australia slaughtered at registered yield prediction processing plants. This may tie in with activities within the Sheep CRC where yields are currently being predicted for numerous sires over the next five years.

A foreseeable problem is the specification of saleable meat yield between different boning rooms (and even between different operators within a boning room!). Different markets have differing trim specifications hence would have differing saleable meat yields for the same animals. Therefore the saleable meat yield of animals would differ between processing plants and this inconsistency would decrease the power of any yield ASBV. For example the difference in saleable meat yields between processing plant operations can be seen when comparing the average lean meat yield of the VIAscan bone-out studies (which have a highly specified level of trim) which has a range between 50-60%lean meat yield. The VIAscan bone-out data sets contrast with this study (with much less intensity applied to the fat trim) which has a saleable meat yield average of about 67%.

For a yield ASBV to be generated and be successfully adopted by the industry, these yield prediction systems need to be correlated. The potential for CATscan technology to become the gold standard in predicting lean, fat and bone is being investigated in a continuation of aspects of this experiment. There is exciting potential for CATscanning to provide the necessary means to correlate and link multiple saleable prediction algorithms situated all over Australia.

7 Recommendations

7.1 Implementation

To integrate the data collection required for the yield prediction algorithms into the operating procedure of Hillside, a weigh table, as described in the discussion should be installed at every table used to breakdown the hindlimb. Alternatively some form of bar code linking the RFID tag for the carcase should be attached to the hindlimb for automated weighing at a bar code enabled weigh point. In conjunction with the weigh tables an RFID number recorder is required, ensuring the data collected at the weigh tables can be linked with all the other data collected from the carcase. Also a boning room cold carcase weight linked with RFID would also be required.

The processing of the information generated on the boning room floor would require sophisticated technology. Consultation by an information technology organisation such as SASTEK could be used to evaluate the feasibility and cost of a system to generate saleable meat yields from boning room weights. The system needs to take into account the boning method being used so the system knows what data is being collected and which algorithm should be used.

7.2 Information

On an individual basis, saleable meat yield prediction still involves some error. But while this may be problematic on an individual animal basis, groups of animals can be compared to evaluate the composition of the carcases in a lot. Different breeds, groups in the feedlot facility at Hillside, the effect of season, and many other variables, can all be investigated in relation to saleable meat yield. Measurements taken on a group basis are thus more likely to be of value for Hillside to provide feedback to producers. Ultimately a saleable meat yield standard could be introduced that would have to be achieved by producers for their animals to be admitted into the Q-lamb program.

8 Appendices

8.1 Appendix 1

SPECIFICATIONS FOR THE BONE-OUT

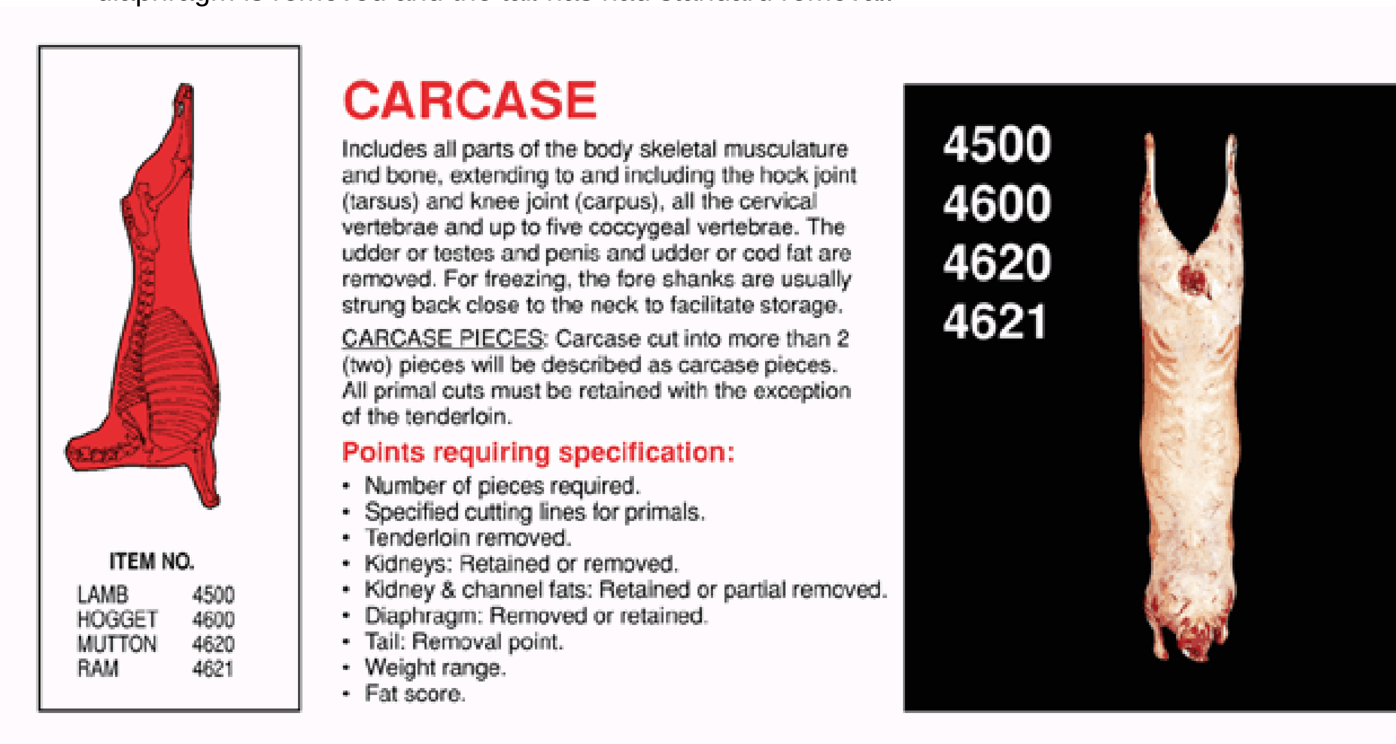
Equipment required

- Sufficient boners that know the specifications well enough to produce consistent results when boning out.
- A scale for weighing the carcases, preferably the same scale used to weight the cuts, if that is not possible then the most accurate scale available.
- A work area for the boners to disassemble the animals
- A band saw
- Five trays divided into meat, bone, meat trim and fat trim. One tub for each of the primaries, rack, breast flap, forequarter, short-loin and the leg.
- Scale to weight the cuts, preferably with a max weight of 15 kg a min weight of .1 kg and an error of .005kg.
- A computer to record the weights.
- A stainless steel table to place the computer and scale on.
- Tubs to place the meat in after it has been weighed.
- Vacuum pack bags for the collection of samples for further analysis.
- Technical Manual of Australian meat

Standard carcase

The animals used in the trial need to be presented in the same form and the trim to be uniform. Below is a list of points that any animal used in the trial must satisfy before being selected. All numbers refer to AUSMEAT standard items.

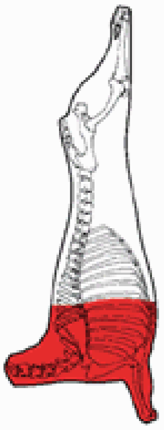
- Any animal that has sustained trim to be passed as food grade is unacceptable and cannot be used in the trial.
- Animals that have superficial damage from the skin puller are ok but carcasses with excessive muscle damage are also to be rejected.
- Animals must pass the specifications for Q-Lamb mentioned in Appendix 1 to be selected for this trial.
- The carcase must be prepared to an AUS-MEAT standard carcase trim, reference number 4500.
- The tenderloin is retained, the kidneys and channel fats are completely removed, the diaphragm is removed and the tail has had standard removal.



Carcase breakdown

The whole animal will be broken down and any weights recorded will refer to the left and right sides of the animal combined.

Separate the carcase into 2 fore quarters 4970/1/2 (find out how many ribs), 2 hind quarters, chump on, 4800 and 2 loins 4860/1/2 (find out how many ribs).



ITEM NO.

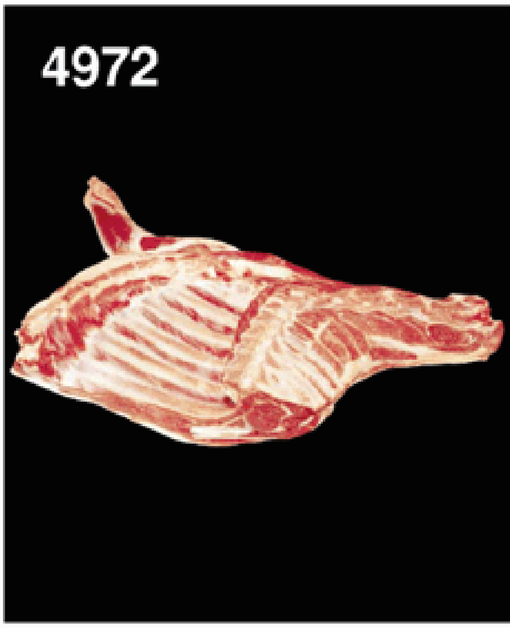
4972 (6-rib)
4969 (13-rib)
4970 (5-rib)
4971 (4-rib)

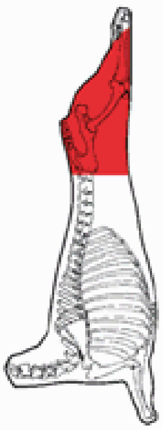
FOREQUARTER

Forequarter is prepared from a side by a straight cut between the specified ribs separating the forequarter and the hindquarter.

Points requiring specification:

- Specify rib number required.
- Fore leg tucked into neck region.





ITEM NO.

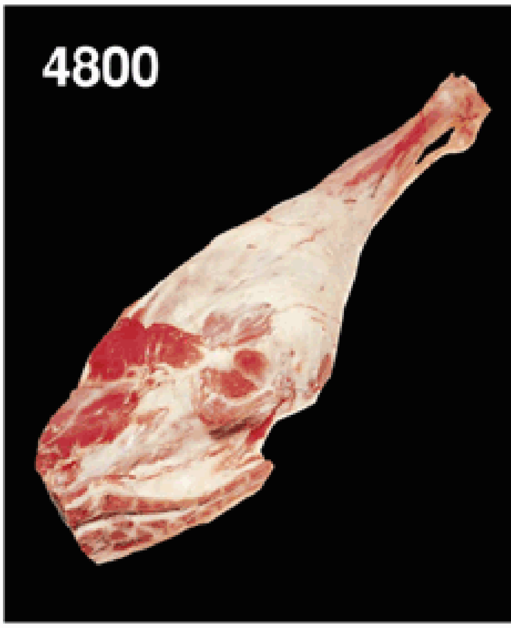
4800

LEG - CHUMP ON

Leg - chump on is prepared from a side by a straight cut through the 6th lumbar vertebrae to a point just clear of the tip of the ilium to the ventral portion of the flank.

Points requiring specification:

- Flank: Retained or removed.
- Tail: Removal point.
- Channel fats: Retained, partial or complete removal.
- Tipped or un-tipped.
- Femur bone only retained.
- Butt tenderloin removed.
- Sacrum: Retained or removed.



ITEM NO.

4860 (8-rib)
4861 (7-rib)
4862 (9-rib)

LOIN

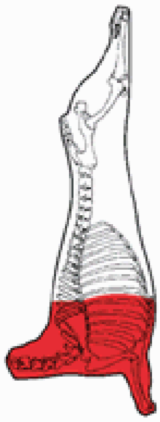
Loin is prepared from a side by the removal of the forequarter along the specified rib, and removal of the leg by a cut passing through the lumbo sacral junction to the flank.

Points requiring specification:

- Rib number required.
- Diaphragm retained or removed.
- Kidney/kidney fat removed or retained.
- Flap removal line & distance from eye muscle.

FOREQUARTER

The forequarters are completely boned out leaving the boneless product 5045/6/7 (find out how many ribs) because of the stringent specifications for Q-Lamb the only ‘fat’ trim required is the removal of the ligamentum nuchae. The neck remains attached.



ITEM NO.

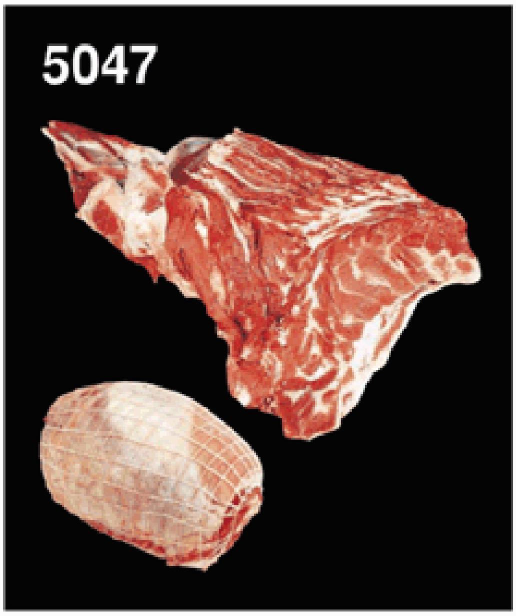
5047 (6-rib)
5046 (4-rib)
5045 (5-rib)

FOREQUARTER

Forequarter is prepared from item 4972 by the removal of bones, cartilage, ligamentum nuchae and lymph nodes.

Points requiring specification:

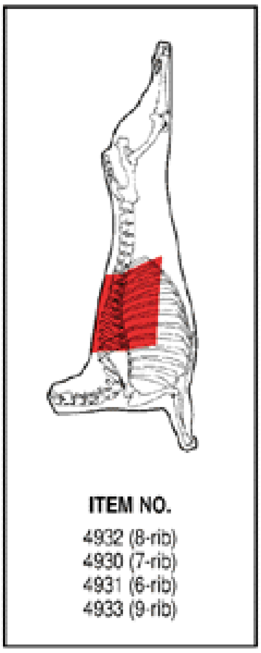
- Rib number required.
- Intercostals retained.
- Rolled and netted.



- Record the weight of the
  - forequarter and the trim and the bones
- then record the weight of the
  - boneless forequarter,
  - the bones, and
  - The ‘fat’ trim or ligamentum nuchae individually.

LOIN

The loin (4860) is further broken down into a rack (4933), flap (5010) and short loin (4880/1 is there a rib?).

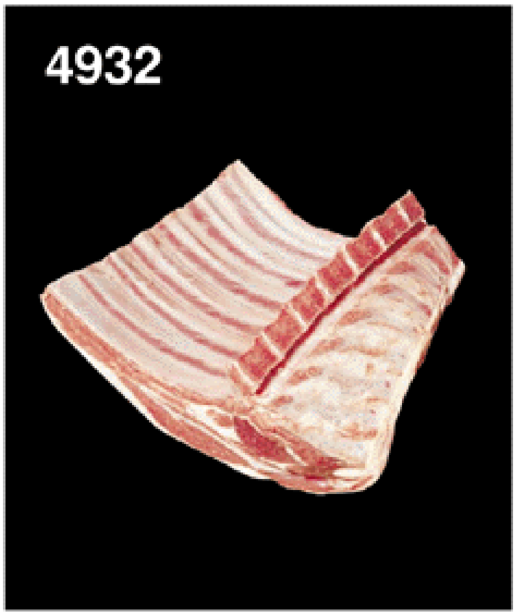


RACK

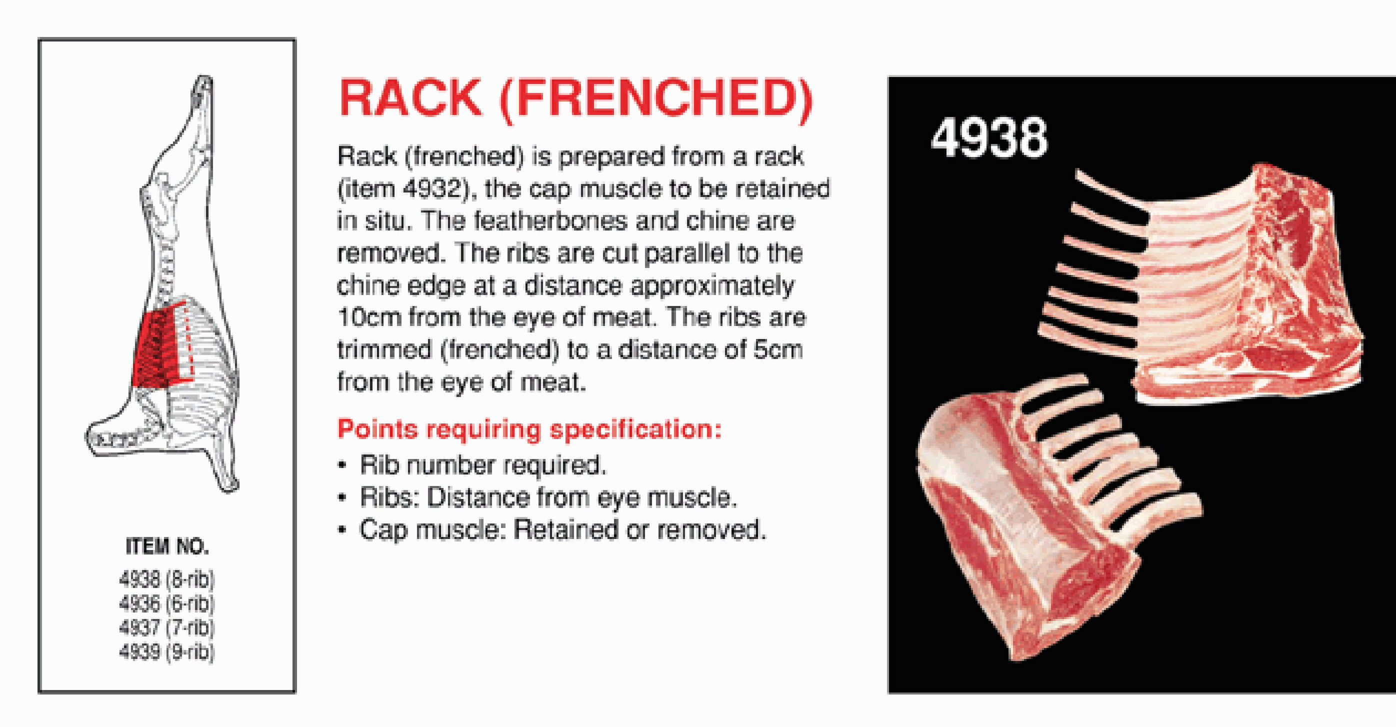
Rack is prepared from a loin (item 4862) by a cut through the M. longissimus thoracis (eye muscle) between specified ribs.

Points requiring specification:

- Rib number required.
- Flap removal line & distance from eye muscle.
- Scapular cartilage removed.
- Feather/Chine bones removed or retained.



RACK (4933)
The rack is frenched (4936/7/8/9 at what distance from the eye muscle), with the cap removed. The intercostals from the frenching are retained and weighed as meat trim and the cap is retained and weighed as fat trim. Separate the eye of the rack (5153), leaving the silver skin on, and the intercostals are removed.



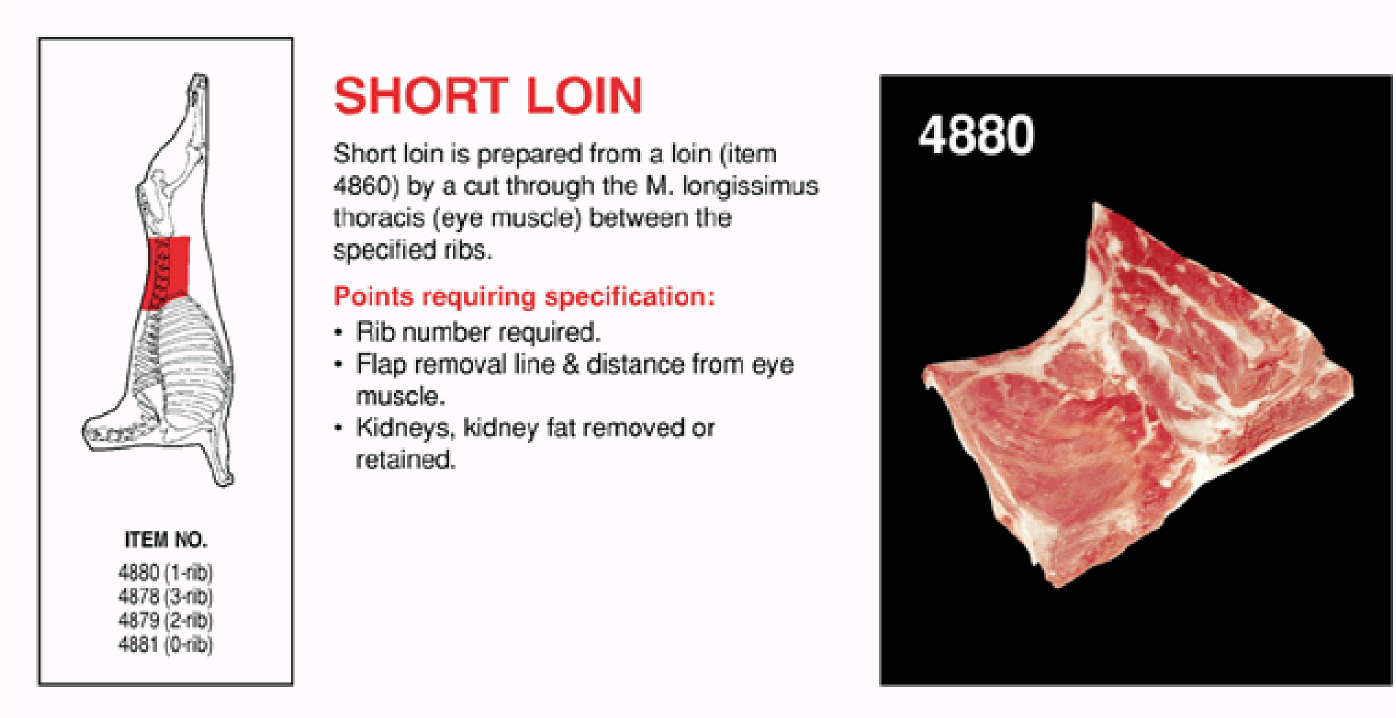
- Record the weights of:
    - The whole rack
- then record the weight of the
    - The eye of the rack (5153) is weighed as meat,
    - The bones with any cartilage is weighed together as bone,
    - The cap and any other fat trim is weighed as fat trim
    - The intercostals and other meat trim are weighed as meat trim.

FLAP (5010)
Remove the meat from the bone and flap

Do not remove the intercostals from the ribs in the flap; they get weighed with the bone.

After weighing the flap, pack one of the boneless flaps (the left or right is suitable) into a plastic bag clearly labelled with the carcase identification number. This will be put aside for chemical analysis. The chemical lean of the flap may need to be calculated to account for the differences in the level of trim from each boner. Since each section of the carcases was boned-out by the same boner determination of the chemical lean of the flap may not be necessary.

SHORT LOIN

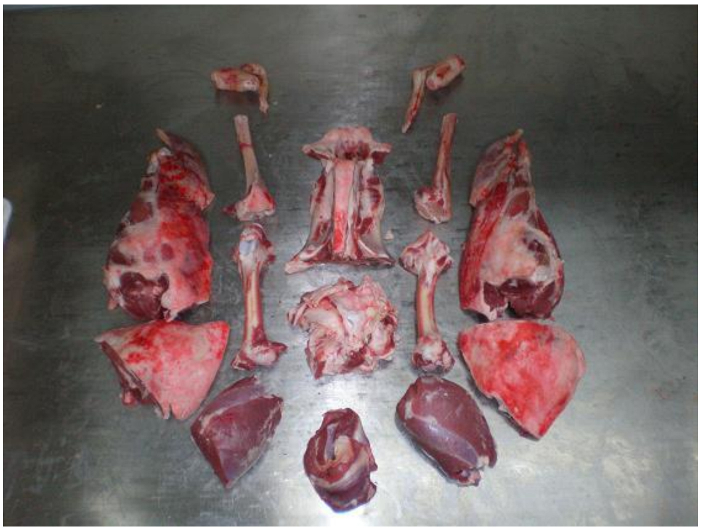


Prior to boning out the short loin photograph the cranial and caudal ends of the short loin with a steel ruler in the field of view, at the same level as the end of the short loin. This is so the caudal and cranial eye muscle area can be determined at a later date with a relevant program. The length of the short loin is also recorded at this point with a steel ruler.

Separate the eye of the short loin, 5150, (retaining the silver skin) and the tenderloins – butt off (5082)

Record the weights of
The eye of short loin and the tenderloin as meat,
Any meat trim as meat trim
Cartilage and bone as bone
Fat trim as fat trim

LEG



Bone out the legs into three individual cuts. The chump (5030), the knuckle (5072) and the easy carve leg. The tibia is removed from the easy carve leg and weighed separately. The flank is weighed as trim.

Record the weights of
The chump,
Knuckle
Leg
Fat trim
Meat trim
The tibia
Rest of the bone

Recording sheet

ID		
CCW		
photo (order)		
BREAST & FLAP	Total (with tray)	
	bone	
	meat trim	
	Flap	
	Breast	
SHORT LOIN	Total (with tray)	
	bone	
	fat trim	
	meat trim	
	meat	
LEG	Total (with tray)	
	Bone	
	tibia	
	fat trim	
	meat trim (shanks)	
	Leg	
	round	
	Chump	
FOREQUARTER	Total (with tray)	
	bone	
	fat trim	
	meat	
RACK	Total (with tray)	
	bone	
	fat trim	
	meat trim	
	meat	