# final report

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# Sheep Meat Eating Quality

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# Abstract

This work was carried out to extend earlier results on sheep (lamb, yearling and mutton) meat eating quality to a range of commercial meat cuts, different methods of cooking (grill, roast, stir fry and slow wet cook) and to examine a wider range of consumer responses than did the first project.

The 5 consumer eating quality scores were shown to be reducable to 3. Discriminant analysis using Overall Liking as the independent variable provided boundaries for classifying the meat of the various animal category x cut x cook into one of 3 groups. Logit calculations gave the probabilities.

The failure rate is the frequency with which the consumer population judged the meat to be unsatisfactory given the overall liking score. Using the failure rate calculation the animal category x cut x cook combinations could be classified into an easy guide for consumers. Based on this classification a simple easy to use chart for retailers was constructed for use by the industry.

# Executive Summary

This work was carried out to extend earlier results on sheep meat eating quality to a range of commercial meat cuts, different methods of cooking (grill, roast, stir fry and slow wet cook) and to examine a wider range of consumer responses. The goal was to classify the eating quality of commercial sheep meat cuts and cooking methods in a manner that could be presented simply to both consumers and participants in the sheep meat supply chain. The outcome of this work is a simple, colour coded easy to understand chart to guide consumer choice based on the frequency with which meat of a given type would fail to meet expectations.

Data on consumer evaluation of the sensory variables (smell, tender, juicy, flavour and overall liking) were collected on 14,280 consumer responses. Each consumer was also asked to place the meat sampling in 1 of 5 categories where 1 represented very unsatisfactory eating quality and 5 represented excellent eating quality.

The analysis proceeded in 2 stages. First the relationships among the sensory variables were analysed to link the consumer responses to measurable quantities. Then these relationships were linked to the consumers judgement of eating quality and used to classify the various animal category x cut type x cooking method combinations in terms of the expected eating quality.

Overall liking of a meat sample was strongly associated with the perceived flavour in all cases. Tender and juicy had minor roles in discriminating between overall liking, while smell tended to be associated with flavour and did not show any independent relationship. There were no practical differences in these relationships between cut type or cooking method. The residual variation within cut type and cooking method was the same. Because of this the overall liking score alone provided the best measurement of the meat sample desirability. That is, there was no improvement in using including any other sensory variables in an index (e.g. a principal component) as a measurement of meat quality. Thus, overall liking alone was chosen as the meat quality measure.

The results of the analysis of the sensory variables can be summerised as follows:

1. Meat from lambs and yearlings is more desirable than meat from ewes.
2. The ranking of the desirability of the cuts over each cooking method was similar between animal category.
3. In all animal categories the relationship with smell is small.
4. Tender is more important in determining desirability in ewes than in lambs and yearlings.
5. Juicy is more important in roasts and stir fry than in grills.
6. If the goal is predictability of overall liking from the other sensory variables then within cooking method and animal category one equation relating overall liking to the other sensory variables can be used for each cut.

While consumers rated the eating quality of the meat into 5 categories there was considerable overlap between categories 1 with 2 and 4 with 5. Combining these categories to produce a 3 point scale provided a much clearer classification, so the 3 point scale was adopted.
The most important characteristic of the consumer judgement of sheep meat eating quality is the variability of the responses. This variability is a natural property of the population of interest, and any scheme to promote sheep meat eating quality must recognise the extent of this variation and include it within any management program. That is, people perceive taste/quality differently, and it is impossible to have a piece of meat where 100% of the people will find satisfactory. The concept of

failure rate was developed in the previous MLA SMEQ project to address this issue. Failure rate measures the proportion of people that will find a piece of meat to be of unsatisfactory eating quality. That is the failure rate is the area under the frequency distribution of the meat quality measure (overall liking) representing the proportion of consumers expected to deem the meat of unsatisfactory eating quality. In this case unsatisfactory meant consumers classifying the meat into category of the 3 point scale. To implement the failure rate classification it was necessary to calculate the appropriate frequency distributions for overall liking for each cut x cook category.

Analysis showed that while the means of overall liking differed between animal category x cut x cook the variances only differed significantly between lambs or yearlings and ewes. Thus there could be 1 form of residual distribution for lambs and yearlings and one for ewes. However, the residual distribution for lambs and yearlings was not Normal – there was significant kurtosis. Therefore a particular form for this distribution had to be calculated. The residual distribution for ewes was normal. Using these calculations the failure rates for each animal category x cut type x cooking method could be calculated. These calculations form the basis of the results presented to industry in the form of a simple colour coded chart to guide the choice of sheep meat by a consumer.

Discriminant analysis provided the optimum partitioning of overall liking score into each of the 3 consumer eating quality categories. That is, the overall liking score below which meat was predicted to be unsatisfactory. Logit analysis provided equations for calculating the frequency (probability) with which meat of given overall liking would be deemed unsatisfactory eating quality. These estimates were used to construct the industry guide to sheep meat eating quality chart.

Analysis of consumer pairs showed that the repeatability of consumer judgements was low but positive (different consumers came to similar judgements of both the sensory variables and eating quality). The low repeatability was due to the high natural variance of these measurements referred to above.

There was little effect of GR fat or ultimate pH on the sensory variables or the meat eating quality.

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# 1 Background - Section

A previous project established the relationships between the sensory variables smell, tender, juicy, flavour and overall liking with the eating quality of sheep meat for a variety of different muscles. This work formulated a probabilistic model of how different aspects of production and processing affected the eating quality of the sheep meat perceived by consumers. The important concept of the failure rate whereby meat of a nominated quality will not meet the expectations of a proportion of consumers was formulated and applied (Pleasants *et al.,* 2005). This concept appeared to be very useful for managing the large amount of variation implicit in any consumers' evaluation of meat quality. This variation is a feature of the population of consumers and it is important that it be quantified and incorporated into any sheep meat eating quality system.

This early project had 2 shortcomings which are addressed in this project. It dealt with singe muscles rather than commercial cuts, and it did not examine a sufficient range of consumer responses to sheep meat quality to get a sufficient understanding of the variability of this product. In addition the current project assessed the effect of the cooking method (grill, roast, stir fry and slow wet cook) on eating quality.

# 2 Project Objectives - Section

- Establish the relationship between the consumer score attributes to discover how overall liking is constructed i.e. develop a model defining the relationship between Overall liking and Tender, Juiciness and liking flavour. In addition analyse the role that 'liking of small' plays in this relationship.
- Determine how the construction of overall liking is affected by animal class (lamb, yearling and mutton) and the extend to which this interacts on a cut x cook basis recognising that there are key 'paired' cut comparisons with fat 'on' or 'denuded'.
- Determine how the components of overall liking in the commercial cuts work compares to the original SMEQ data based which was developed using denuded muscles
- Use a 'paired consumer analysis' to identify rogue consumers and quantify the importance of this to the 'consumer based' variance term
- Partition the variation due to consumers, animal age, carcass weight, GR, PHu, property of origin and cooking method.
- For each cut x cook x age class construct a frequency distribution of overall liking that can be identified to satisfaction.
- For each cut x cook x age class construct 'satisfaction' table based on the modelling of satisfaction alone and contrast this table to the one above (i.e. based on a frequency distribution of overall liking that can be identified to satisfaction.
- Publish a paper reporting the results of the analysis.

# 3 Methodology - Section

The analysis analysed the responses of 14,280 consumer evaluations of the sensory variables (overall liking, smell, tender, juicy and flavour) each scored from 1 to 100, and the eating quality on a 5 scale of 1 (lowest) to 5 (highest). The data was classified by animal type (lamb, yearling, ewe), commercial cut type and cooking method (grill, roast, stir fry, slow wet cook).

The goal of the first set of milestones in this project was to establish the relationship between overall liking and the sensory variables, smell, tender, juicy and flavour. The methodology is similar to the earlier project in sheep meat eating quality which classified the meat quality according to the frequency (probability) that the meat will fail to meet consumer expectations. In this case the relationship is to be defined in terms of commercial cuts and the method of cooking.

Thus, interest is focussed on the regression between overall liking and the other sensory variables (smell, tender, juicy, flavour). In particular, how this relationship might change as commercial cut and cooking method change, and also on the nature of the residual frequency distribution since this will characterise the form of the failure rate as a frequency.

Partitioning of the variation in Overall Liking for consumers, animal age, carcass weight, GR, pHu, property of origin and cooking method was carried out by analysis of variance and regression. Partition of variation in the consumer evaluation category (CEC) truncated to 3 categories was carried out using logit regression.

The relevant cut x cook x age class frequency distributions were based on the residual frequency distributions found from the analysis of variance of cut and cook within animal age class. Where the frequency distribution was significantly and importantly different from Normal a suitable empirical distribution was constructed by modifying the Normal distribution by a suitable polynomial expansion (Buckland, 1992). This was important since the failure rate is defined by the nature of the residual frequency distribution of the cut of interest – i.e. the frequency (probability) with which a cut with a given Overall Liking score will fail to deliver at least a good eating quality experience to a consumer. Thus it is important to have a good estimate of this statistic. .

A discriminant analysis based on the CEC scores provided the optimum cut off overall liking scores for consumer eating satisfaction as defined by the 3 eating quality categories (unsatisfactory, good every day and excellent). Applying these cut-off scores to the appropriate residual frequency distributions linked overall liking to the consumer eating quality of the sheep meat.

A more general estimate of the relationship between Overall Liking and consumer satisfaction was derived by finding the logit regression of Overall Liking on the CEC score within each cut × cook. Algebraic manipulation of this regression gave the probability that any cut × cook with a given Overall Liking would fall within each of the 3 eating quality categories.

# 4 Results and Discussion - Section

The numbers of consumer responses, classified by animal category and cooking method, are shown in Table 1.

The frequency distributions for each of the sensory variables measured are shown in Figure 1. It is clear that a number of consumers are adopting a measurement scale based on rounding up their evaluations to the nearest ‘10’. This is exactly what happened with consumer evaluations in the previous project on sheep meat eating quality, i.e. consumers tended to score on a 10 point scale or a 100 point scale.

The correlations among the sensory variables are shown in Table 2. These correlations were similar for each of the animal categories (lamb, yearling and mutton).

There was no significant difference between lambs and yearlings for eating quality. However, for practical purposes these animal categories continued to be considered separately. Ewes had a lower eating quality as measured by overall liking, and are also treated separately.

The relationship between overall liking and smell, tender, juicy and flavour are considered under each cooking method (grill, roast, stir fry and slow wet cook), and for each cut within each cooking method. The model for each cooking method was:

Overall liking = mean + cut + smell + tender + juicy + flavour + residual (1)

## 4.1 Lambs and Yearlings

### 4.1.1 Grill

The least squares means for cut by grill are shown in Table 3 for Lambs and Yearlings ranked from the least desirable to the most desirable cut for grilling. Meat cuts that are not significantly different ($P > 0.05$) have different superscript integers.

The relationship between the sensory variables for lambs is given by the regression:

Overall Liking = cuts + 0.26(tender) + 0.72(flavour). (2)

with standard deviation 2.7 units. And for yearlings:

Overall Liking = cuts + 0.15(tender) + 0.10(juicy) + 0.75(flavour)

with standard deviation 2.6 units.

The regression coefficients for the relationship between overall liking and smell, tender, juicy and flavour, and the residual standard deviation for each cut within cooking by grilling is given in Table 4. There is a slight trend for smell to become more important and flavour to become less important as the desirability of the cut increases.

However, the regression coefficients calculated for the individual cuts do not differ significantly from the compound regression above (equation 2). In particular the residual standard deviations are similar, which means that in terms of predictability the regression (2) would perform as well as using separate regression coefficients for each cut.

### 4.1.2 Roast

The least squares means for cut by roast are shown in Table 5 ranked from the least desirable to the most desirable cut for roasting. Meat cuts that are not significantly different (P > 0.05) have different superscript integers

The relationship between the sensory variables for lambs is given by the regression:

Overall Liking = cuts + 0.19(tender) + 0.13(juicy) + 0.73(flavour). (3)

The standard deviation of this relationship is 2.4 units.

The relationship between the sensory variables for yearlings is given by the regression:

Overall Liking = cuts + 0.11(smell) + 0.17(tender) + 0.12(juicy) + 0.65(flavour)

The standard deviation is 2.6 units.

There was no statistical difference between lambs and yearlings across all cuts.

The regression coefficients for the relationship between overall liking and smell, tender, juicy and flavour, and the residual standard deviation for each cut within cooking by roasting is given in Table 6. There is a tendency for juicy to become less important and for flavour to become more important as cuts become more desirable for roasting.

Similar to the method of cooking by grilling the regression coefficient calculated for each cut are similar to the regression coefficients calculated across all cuts (equation 3). Also, the standard deviation from the regression across all cuts is similar to the standard deviations of the regressions of the individual cuts. Thus, for predictive purposes there is nothing to be gained from using separate regression coefficients based on each cut.

### 4.1.3 Stir Fry

The least squares means for overall liking for cut by stir fry for lambs and yearlings are shown in Table 7 ranked from the least desirable to the most desirable cut for stir fry. Meat cuts that are not significantly different (P > 0.05) have different superscript integers

These estimates are not significantly different from each other for lamb.

The relationship between the sensory variables for lambs is given by the regression:

Overall Liking = 0.13(smell) + 0.18(tender) + 0.13(juicy) + 0.70(flavour). (4)

The standard deviation of this relationship is 2.6 units.

The relationship between the sensory variables for yearlings is given by the regression:

Overall Liking = cuts + 0.25(tender) + 0.22(juicy) + 0.61(flavour)

The regression coefficients for the relationship between overall liking and smell, tender, juicy and flavour, and the residual standard deviation for each cut within cooking by stir fry is given in Table 8. The regression coefficients for the individual cuts are different from the regression coefficients of equation (4). In the individual cuts tender appears to be unimportant in judging eating quality while juiciness is more important. The importance of juiciness decreases as the desirability of the cut increases (Table 8).

While the regression coefficients for the individual cuts differ from the collective regression (equation 4), the residual standard deviations are similar. Thus, for prediction the collective regression (4) would be as accurate as the individual regressions for evaluating sheep meat eating quality for stir fry.

### 4.1.4 Slow Wet Cook

The least squares means for cut by stir fry for lambs and Yearlings are shown in Table 9. Meat cuts that are not significantly different ($P > 0.05$) have different superscript integers

The relationship between the sensory variables for lambs is given by the regression:

Overall Liking = cuts + 0.29(juicy) + 0.68(flavour).

The standard deviation of this relationship is 2.1 units.

For yearlings the regression is:

Overall Liking = cuts + 0.71(flavour)

The standard deviation of this relationship is 2.8 units.

The regression coefficients for the relationship between overall liking and smell, tender, juicy and flavour, and the residual standard deviation for each cut within cooking by SC2 is given in Table 10.

## 4.2 Ewes

### 4.2.1 Grill

The least squares means for cut by grill for ewes are shown in Table 11 ranked from the least desirable to the most desirable cut for grilling. Meat cuts that are not significantly different ($P > 0.05$) have different superscript integers

The relationship between the sensory variables is given by the regression:

Overall Liking = cuts + 0.27(tender) + 0.03(juicy) + 0.64(flavour).

The standard deviation of this relationship is 10.5 units.

The regression coefficients for the relationship between overall liking and smell, tender, juicy and flavour, and the residual standard deviation for each cut within cooking by grilling is given in Table 12. There is a tendency for the residual standard deviation to be higher for the less desirable cuts.

### 4.2.2 Roast

The least squares means for cut by grill for ewes are shown in Table 13 ranked from the least desirable to the most desirable cut for roasting. Meat cuts that are not significantly different ($P > 0.05$) have different superscript integers

The relationship between the sensory variables is given by the regression:

Overall Liking = cuts + 0.21(tender) + 0.16(juicy) + 0.61(flavour).

The standard deviation of this relationship is 7.5 units.

The regression coefficients for the relationship between overall liking and smell, tender, juicy and flavour, and the residual standard deviation for each cut within cooking by roasting is given in Table 14.

### 4.2.3 Stir Fry

The least squares means for cut by stir fry for ewes are shown in Table 15 ranked from the least desirable to the most desirable cut for stir fry. Eye of loin strips was significantly more desirable than any of the other cuts. Meat cuts that are not significantly different (P > 0.05) have different superscript integers

The relationship between the sensory variables for ewes is given by the regression:

Overall Liking = cuts + 0.18(juicy) + 0.90(flavour).

The standard deviation of this relationship is 2.6 units.

The regression coefficients for the relationship between overall liking and smell, tender, juicy and flavour, and the residual standard deviation for each cut within cooking by stir fry is given in Table 16.

### 4.2.4 Slow Wet Cook

The least squares means for cut by Slow Wet Cook for ewes are shown in Table 17 ranked from the least desirable to the most desirable cut for Slow Wet Cook. The Fore Shank was significantly less desirable than the Hindshank Casserole.

The relationship between the sensory variables for ewes is given by the regression:

Overall Liking = cuts + 0.29(juicy) + 0.67(flavour)

The regression coefficients for the relationship between overall liking and smell, tender, juicy and flavour, and the residual standard deviation for each cut within cooking by stir fry is given in Table 18.

## 4.3 Summary of the Relationships of Sensory Variables to Overall Liking

1. Meat from lambs and yearlings is more desirable than meat from ewes.
2. The ranking of the desirability of the cuts over each cooking method was similar between animal category.
3. In all animal categories the relationship with smell is small.
4. Tender is more important in determining desirability in ewes than in lambs and yearlings.
5. Juicy is more important in roasts and stir fry than in grills.
6. If the goal is predictability of overall liking then within cooking method and animal category one equation relating overall liking to the other sensory variables can be used for each cut.

# 5 Denuded Cuts v Fat on Cuts

Table 19 shows a comparison of the regression coefficients for overall liking on the other sensory variable for the paired cuts with fat on or denuded of fat. Except for roast Yearling and Lamb cuts denuded of fat rated variation in juicy more important than for cuts with fat on. .

# 6 Consumer repeatability

An assessment of the repeatability of consumer taste preferences could be made by fitting the model:

$$Y = \mu + \text{animal category} + \text{cook} + \text{cut within cook} + \text{pair} + \text{error}$$

where pair denotes a consumer pairing in the trial design. Treating pairs as a random component the intraclass correlations measure how much more alike the sensory variables are within a consumer pair (tasting essentially the same meat) than between consumer pairs. The intraclass correlations are

Smell 0.06; Tender 0.14; Juicy 0.14; Flavour 0.12; Overall 0.14

Except for smell there is a small degree of agreement on the desirability when the same sheep meat is tasted by different people. This repeatability estimate reflects the large amount of between consumer variation in their evaluation of sheep meat eating quality. Given this characteristic of eating quality the repeatability estimates are evidence that there is some general agreement in the population of the eating quality of meat with different characteristics and under different methods of cooking.

# 7 Identifying Rogue Consumers

Within animal category and cooking method the model

$$Y = \mu + \text{cut} + \text{pair} + \text{consumer within pair} + \text{error}$$

The factor between consumer within pair was significant for lambs and yearlings, but not for ewes on grills and roasts. However, in each case the distribution of consumer within pair responses had a normal distribution with a standard deviation of about 3 units. This suggests that the observed between consumer within pair differences were natural and not due to rogue elements.

Removing the consumer pairs that were more than 2 standard deviations from the mean (numbers 1, 23, 53) for grilled lamb and yearlings did not alter the values of the regression coefficients. Neither did this affect the error term. This response would be expected from the small number of consumer pairs identified.

Thus, the suspicion that rogue consumers existed appears untrue, and seems to be a quality of the naturally large amount of between consumer variation measured in this work. That is, given the high variance associated with consumer judgement a wide range of judgements of the eating quality of a particular piece of meat is to be expected, and indeed this is the case.

# 8 The Role of Liking of Smell

The sensory variable contributing the least to the response of Overall Liking was the variable Liking of Smell. This despite consumers recording a similar variability to this attribute (standard deviation of 20 units compared to standard deviations of 24 units for tender, juicy and flavour). That is, although consumers were able to recognize differences in smell they did not rate this variable in determining how desirable the meat was.

It is likely that the variance in Overall Liking associated with Like Smell is contained in the variances in Overall Liking associated with the other sensory variables.

However, Liking of Smell is the sensory variable most unrelated to the other sensory variables. It appears that most consumers ignored the smell and concentrated their evaluation on the other sensory variables. Perhaps any notable effect of smell was intuitively integrated into the flavour effect by consumers.

When flavour is removed as an independent variable Smell becomes a significant and important component of Overall Liking. For example, for lambs and yearlings there is a regression with flavour included as an independent variable:

$$\text{Overall Liking} = \mu + \text{cook} + \text{cut within cook} + 0.18(\text{tender}) + 0.11(\text{juicy}) + 0.73(\text{flavour})$$

with a standard deviation of 8.3 units.

With smell included as an independent variable instead of flavour:

$$\text{Overall Liking} = \mu + \text{cook} + \text{cut within cook} + 0.27(\text{smell}) + 0.36(\text{tender}) + 0.38(\text{juicy})$$

with a standard deviation of 14.7 units.

Thus, there is a degree of trade – off between Liking of Smell and Flavour, although the error when using smell instead of flavour in the regression is considerably greater. Note also the greater influence of tender and juicy when flavour is omitted from the relationship.

This relationship was not changed by considering different subsets of Overall Liking. It might be hypothesised that Liking Smell would be more important in determining desirability when overall liking was below average. But analysing the data using only those observations above or below the general mean of overall liking produced much the same results.

One factor that may influence these issues is the relative error with which each of the sensory variables can be estimated using production and processing factors. In the current data set all the sensory variables (evaluated by the consumers) have the same variability (raw standard deviation of about 24 units). But for example, if the estimate of flavour in the supply chain had greater variance than the estimate of smell (because of better measurement techniques?) then a prediction equation using smell instead of flavour might be more favourable.

# 9 Choosing the Number of Quality Classes

The criteria for choosing the number of quality classes would appear to be:

- There should be a sufficient proportion of meat available for each class.
- In adopting the failure rate criteria there should be a sufficient margin to ensure a low failure rate while maintaining enough of the product.
- The cost of introducing another class should be less than the benefit expected.

Thus, the number of classes to have depends on estimates of consumers demand, value and cost.

# 10 Effects of GR, Ultimate pH and Source of the Animals

Lambs showed significant ($P < 0.05$) effects of the GR measure on tender ($b = 0.33$), juicy ($b = 0.39$), flavour ($b = 0.35$) and overall liking ($b = 0.35$). There was no effect of carcass weight. Yearlings showed no relationship of carcass weight or GR with these sensory variables, nor any relationship of dentition with these sensory variables. However, when examined within cooking method and after accounting for differences between cuts there was no significant relationship between overall liking and the GR measurement in lambs or yearlings. Ewes showed a significant ($P < 0.001$) effect of GR after accounting for cooking method and cut type. For grilling the regression coefficient of overall liking on GR was 1.199 ± 0.363, and for roasting the regression coefficient was 1.319 ± 0.388. The implication is that a decision on the quality of mutton would be improved by knowing the GR measure, but not for lambs or yearlings.

Ewes showed significant ($P < 0.01$) differences between the sources from which the animals were obtained for all the sensory variables.

There were no ultimate muscle pH relationships with any of the sensory variables in lambs or yearlings. There was a significant ($P < 0.01$) effect of ultimate pH on overall liking for mutton roasts ($b = -11.08 \pm 4.92$), but not for grilling. The correlation between ultimate pH and GR in ewes was -0.23, so that fatter ewes had lower pH. There was no such relationship in lambs and yearlings.

Carcass weight was correlated with GR in which was the same in all 3 animal age classes ($r = 0.52$).

# 11 Consumer scores

Each cut x cook sample was evaluated for acceptability on a scale of 1 to 5. This evaluation defined a multinomial frequency distribution which gave the probabilities that sheep meat from that cut x cook would meet the degree of acceptability from unacceptable to excellent.

$$P[x_1, x_2, x_3, x_4, x_5] = \frac{N!}{x_1!x_2!x_3!x_4!x_5!} p_1^{x_1} p_2^{x_2} p_3^{x_3} p_4^{x_4} p_5^{x_5} \quad (5)$$

where $\sum_i p_i = 1$

The maximum likelihood estimates of the multinomial probabilities ($p_i$) are just the proportions of the cut x cook allocated to each score by the consumers.

For large numbers the multinomial distribution can be approximated by the multinormal distribution with parameters:

$$\mu_i = Np_i \quad \sigma_i^2 = Np_i(1-p_i) \quad \sigma_{ij} = -Np_i p_j$$

The most common application will be to decide the SMEQ score for the cut x cook category. The SMEQ score describes the expected failure rate of the cut x cook category. This requires the failure rate to be defined. For example, a suitable SMEQ score might be the probability that 90% of the cut x cook samples will be acceptable, deemed to be a rating of 3 or more.

While the multinomial frequencies give the population acceptability of the cut x cook, the calculation must take into account that a typical retailer will generally take a sample (10 – 100?) cuts from the population. Thus, there will be a probability of getting cuts with more or less acceptability in the sample than occurs in the full population. That is, a particular cut might have a probability of 0.1 of being unacceptable in the population. However, it is unlikely that a retailer acquiring a number of cuts from this population will have exactly 10% unacceptable. It is this sampling variation that must be taken into account when calculating the failure rate.

An example will illustrate the point. Assume that ratings of 1 or 2 are unacceptable product, while ratings of 3 to 5 are acceptable eating quality. A cut has a probability of 0.14 of being unacceptable for grilling and a probability of 0.86 of being acceptable for grilling. If a retailer receives 100 cuts, the probability of getting *n* unacceptable samples in this set of 100 cuts is shown in Figure 2.

The information in Figure 2 can be summarised in a number of ways. For example, the probability that at least 90% of the shipment is acceptable is 0.84. Thus a SMEQ score could be defined as 84 for this cut when it is grilled. Similarly consider a cut that that had a probability of 0.05 of being unacceptable for roasting, and a probability of 0.95 of being acceptable. A retailer receiving 100 cuts would calculate that the probability of at least 90% of the shipment being acceptable is 0.99, giving a SMEQ score for this cut of 99.

Using this methodology a sub - classification is possible for valuable cuts. Using the example above the probability that at least 50% of the shipment will be rated 4 stars or higher is 0.03, giving a SMEQ excellence score of 3. Alternatively, the probability that at least 40% of the shipment will be rated 4 stars or better is 0.54, so another SMEQ excellence score could be 54 for this cut.

# 12 Choosing an Eating Quality Discrimination Measure.

The Overall Liking score given by the consumers was chosen as the measurement which most described the eating quality as perceived by the consumers. The first principal component of the sensory scores was not as closely correlated with eating quality as was overall liking score, nor were any other sensory score combinations that were considered. This confirmed the results found in the first MLA sheep meat eating quality project.

# 13 Discriminant Analysis

Consumers ranked the samples into 5 eating quality categories (stars). Comparing this classification with the measurement "overall liking" shows that there is considerable overlap among the categories 1 and 2 as well as categories 4 and 5 for overall liking (Figure 3). This suggests a reduction to 3 eating quality categories by combining categories 1 and 2 to give category 2, and categories 4 and 5 to give category 4. The result of this is shown in Figure 4. The discrimination among the 3 categories is much clearer than among the original 5.

The results of applying discriminant analysis using overall liking as the variable to allocate a meat cut to each of the 3 eating quality categories for each animal category by cooking method is given in Table 20. This Table shows the value of the overall liking score which forms the boundaries between eating quality categories 2 and 3, and eating quality categories 3 and 4, and the expected failure rates for categories 3 and 4. Category 2 is deemed unsatisfactory (failure). The boundaries for each animal category and cooking method are remarkably similar, and so are the relative failure rates. The exception is the slow wet cook method of cooking which conforms less than the other cooking methods.

The results shown in Table 20 suggest that an eating quality classification based on the measurement of overall liking and the discriminant function based on the 3 EQ categories would have an average failure rate of about 15%.

Tables 21 to 32 show the estimated failure rates for each of the cut by cooking methods for the 3 categories of animal based on the calculated discriminant function.

However, discriminant analysis puts equal weights onto the failures both above and below the cut – off point. That is, the analysis weights a mistake of classifying an EQ rate of 2 as an EQ rate of 3 in the same way as a mistake of classifying an EQ rate of 3 as an EQ rate of 2. But a sheep meat grading system will probably consider the first mistake more serious than the second mistake. If only the first mistake, that of grading meat too high is considered, this makes things easier since the discriminant boundary can then be moved to set any desired failure rate.

The additional information about eating quality provided by overall liking can be expressed as the conditional probability distribution $P[EQ|overall]$. However, if the particular value of overall liking is not known, but is a random variable that is either estimated or obtained as the result of some indirect measurement then:

$$P[EQ] = \int P[EQ|overall]P[overall]d(overall) \quad (6)$$

The form of the residual overall liking distribution (after accounting for animal category and cut type) is shown as a histogram in Figure 5 with a Normal distribution superimposed for comparison. Residual overall liking is not normally distributed. The non – normal nature of this distribution must be taken into account in the above calculation. This can be done by using the empirical residual distribution (i.e. a histogram for the actual residuals) or by using a theoretical distribution. In each case the least squares estimate of the cut x cook x animal category effect is used as the mean of the distribution.

The computer program “cutpoint.for” written in fortran and supplied to the MLA in executable code calculates the appropriate “overall” boundary point for any desired failure rate entered into the program.

# 14 Logit Analysis

The conditional probability of eating quality given the overall liking score is found by calculating the logit regression and using the regression coefficients to find the appropriate probabilities. The regression coefficients for the multinomial logit with 3 EQ classes are shown in Table 33 for each animal category × cook. These regression coefficients are calculated using the individual data.

A logit analysis has an advantage over a discriminant analysis in that the probabilities for each of the 3 eating quality categories can be calculated given the Overall Liking. That is it calculates the conditional probability given in equation (7). This is accomplished using the formula:

$$P_{CEC}[CEC = 3 | OL] = \frac{1}{1 + \exp(a_1 + b_1\,OL) + \exp(a_2 + b_2\,OL)}$$
$$P_{CEC}[CEC = 2 | OL] = \exp(a_2 + b_2\,OL)\,P_{CEC}[CEC = 3 | OL] \qquad (8)$$
$$P_{CEC}[CEC = 1 | OL = \exp(a_1 + b_1\,OL)\,P_{CEC}[CEC = 3 | OL]$$

where $a_i$ and $b_i$ are the logit regression coefficients for the $i^{th}$ eating quality categories shown in Table 33.

The program Logit probability supplied to the MLA in executable code calculates these probabilities from an input Overall Liking score. The program is supplied to the MLA in executable code. The program is written in pascal calculates the EQ class probabilities for each animal category and cooking method for any value of “overall” submitted to the program.

# 15 Estimates of the Expected Failure Rate and the Expected Excellent Rate

The equations (3) above give *P[EQ | Overall Liking]* in equation (2). The probability density for Overall liking for each cut within each cut x cook for lambs and yearlings is not normal. It was calculated by modifying a Gaussian distribution by a series of polynomials (Buckland, 1992). The equation is:

$$\frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(Ol-\mu)^2}{\sigma^2}} \left[1 - 0.044\left(OL^4 - 6OL^2 + 3\right) - 0.1833\left(OL^3 - 3OL\right)\right] \qquad (9)$$

For ewes the probability density of the Overall Liking residuals is Normal.

This formulation is necessary as an accurate calculation of the failure rate depends on a good estimate of the probability distribution, especially the size of the tails of the distribution. The standard deviation of the residual of Overall Liking is 23 for lambs and yearlings and 25 for ewes.

Equations (8) and (9) are entered into equation (7) to calculate the expected failure rate given by the probability (frequency) that a cut with a given average Overall Liking will be judged unsatisfactory by consumers. This equation is also used to calculate the expected excellence rate, which is the probability (frequency) that a cut with a given average Overall Liking will be judged excellent by consumers. These estimates are shown in Tables 21 to 32.

Since it was felt that the data set for ewes may not be a representative sample a subset of ewes which had pH less than 6 and more than 6mm GR fat were selected. The estimated failure rates for these animals are shown in brackets in Tables 29 to 31. This selection improves the failure rate of many of the cuts having large failure.

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# 16 Construction of the SMEQ Cut x Cook Table

After discussion with other members of the SMEQ analysis team the above results were used to construct a recommended cut x cook table that can become a tool for the industry to guide consumers to choose a suitable cut and cooking method for their purpose. This table represents the practical application of the results reported here.

# 17 Publication of a Science Paper Reporting These Results

A paper entitled 'Evaluating Sheep Meat Eating Quality in Australia' by D.W. Pethick, A.B. Pleasants, A.M. Gee and D.L. Hopkins has been accepted for publication in the Proceedings of the New Zealand Society of Animal Production 2006. This is a peer reviewed journal. The paper reports on partial results – namely the effect of the roast method of cooking only,

# 18 Success in Achieving Objectives - Section

The project was successful in constructing a format for consumers to choose a sheep meat product to meet their purpose, based on the failure rate concept developed in an earlier project. All milestones were achieved, and some ancillary issues whose importance was realised as the project progressed were dealt with.

# 19 Impact on Meat and Livestock Industry – now & in five years time - Section

The concept of failure rate and its management is the foundation concept to this work, and is seminal in acknowledging the primary role of variation in consumer appreciation and perception of the eating quality of meat. The temptation is to ignore the degree of variability that occurs, but by incorporating this issue directly both a better understanding of the product is obtained and a better appreciation of the degree of control are possible. The paradigm shift of accepting and managing irreducible variation in sheep meat eating quality as perceived by consumers represents an advance in thinking that the industry can build on in the future. This building will be carried out by extension personnel, and the results of this project may provide concrete examples to assist this.

# 20 Conclusions and Recommendations - Section

This project has supplied a tangible tool for marketing sheep meat to consumers. There are no particular conclusions or recommendations following from this.

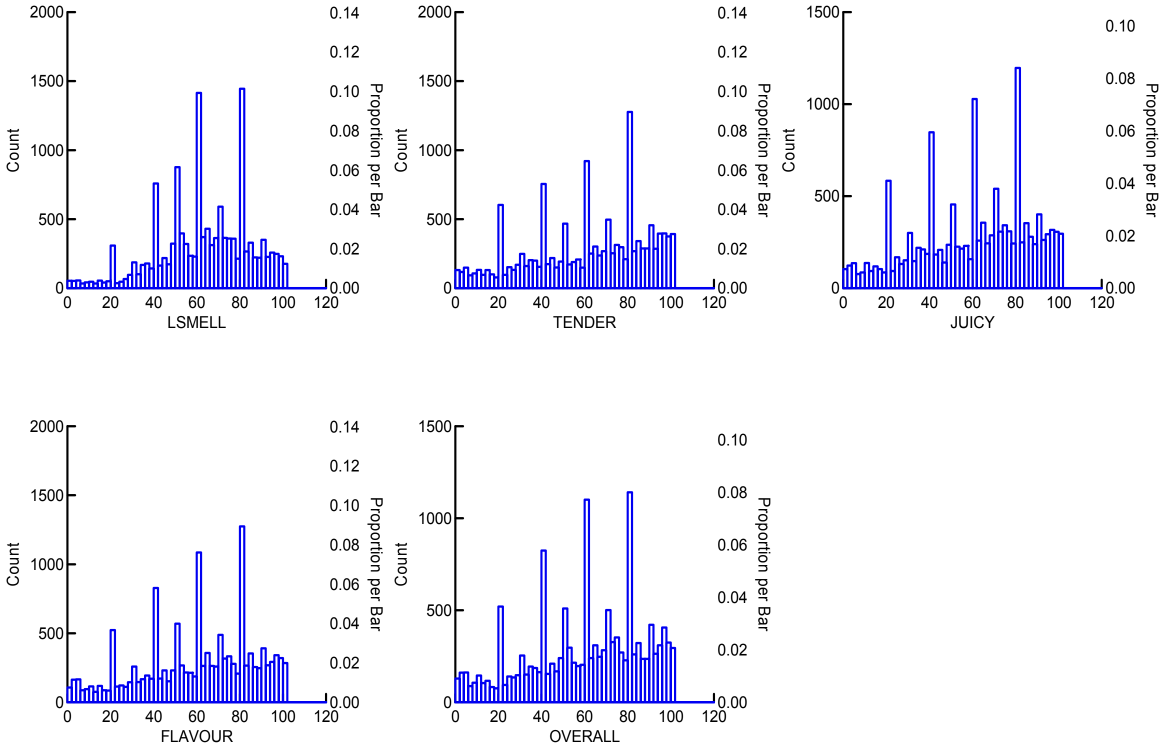
# 21 Bibliography

Buckland, S.T. 1992. Fitting density functions with polynomials. *Applied Statistics* **41** (1) 63 -76.

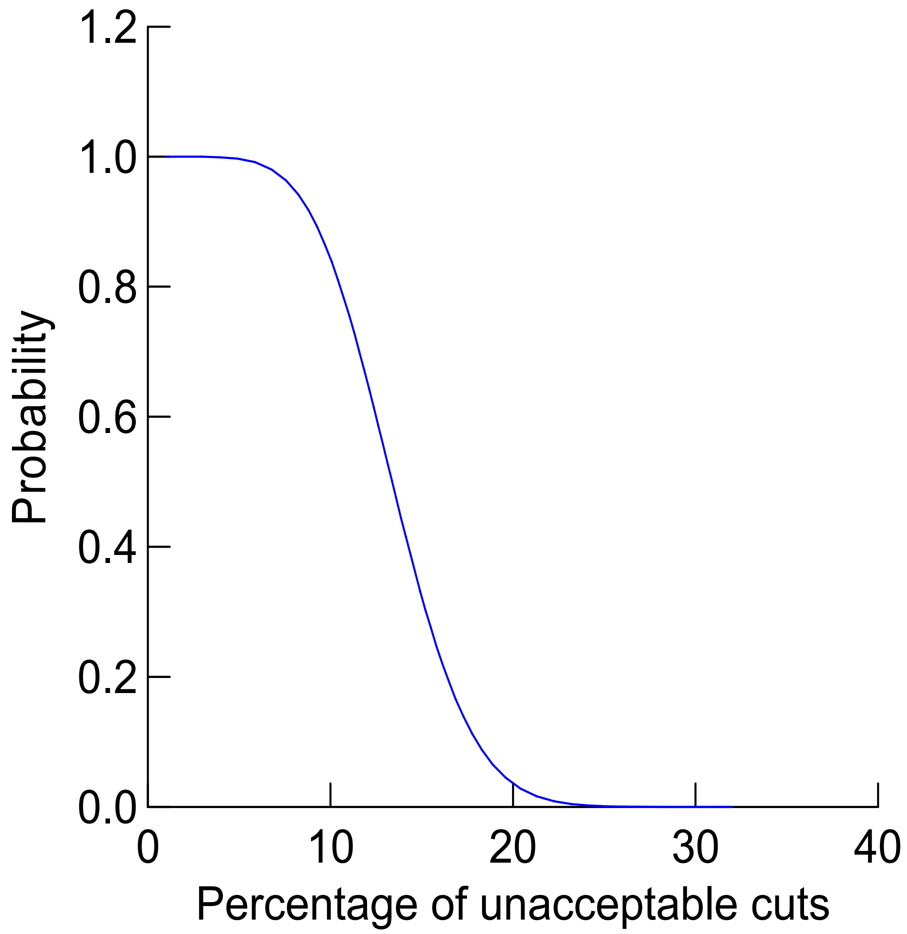
Pleasants, A.B., Thompson, J.M., Pethick, D.W. 2005. A model relating a function of tenderness, juiciness, flavour and overall liking to the eating quality of sheep meat. *Australian Journal of Experimental Agriculture* **45** 483 – 489.

# 22 Appendices

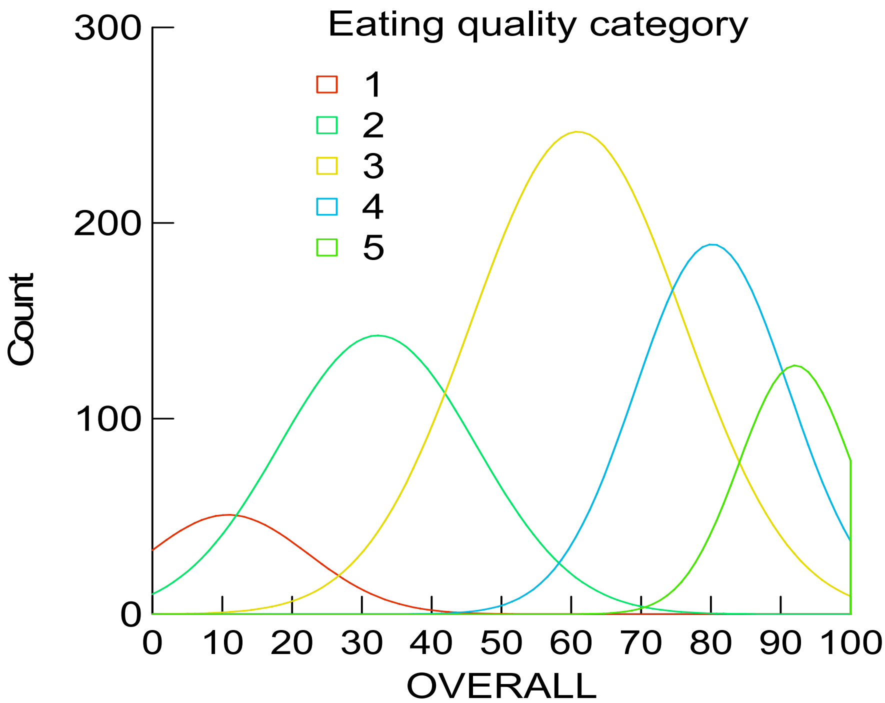
## 22.1 Figure 1: Frequency distributions for each of the sensory variables.



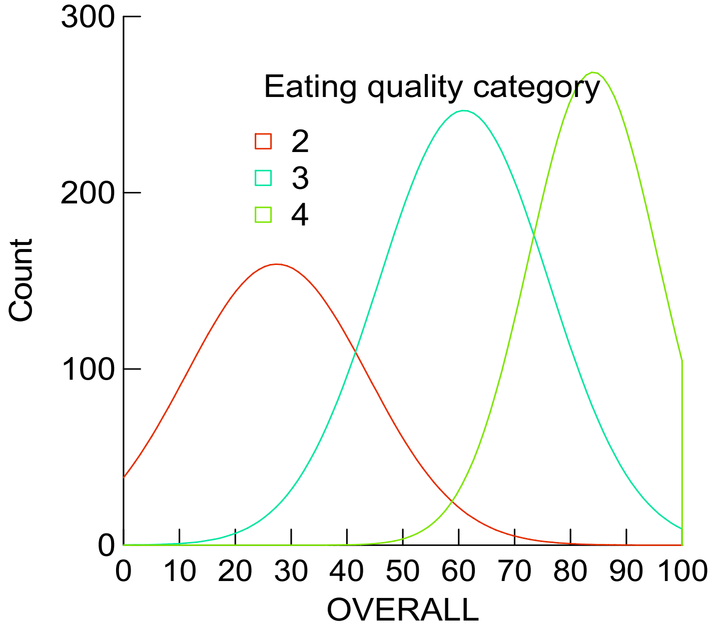
**22.2 Figure 2: Probability of percentage of unacceptable cuts in a sample of size 100 with a probability of unacceptability of 0.14**



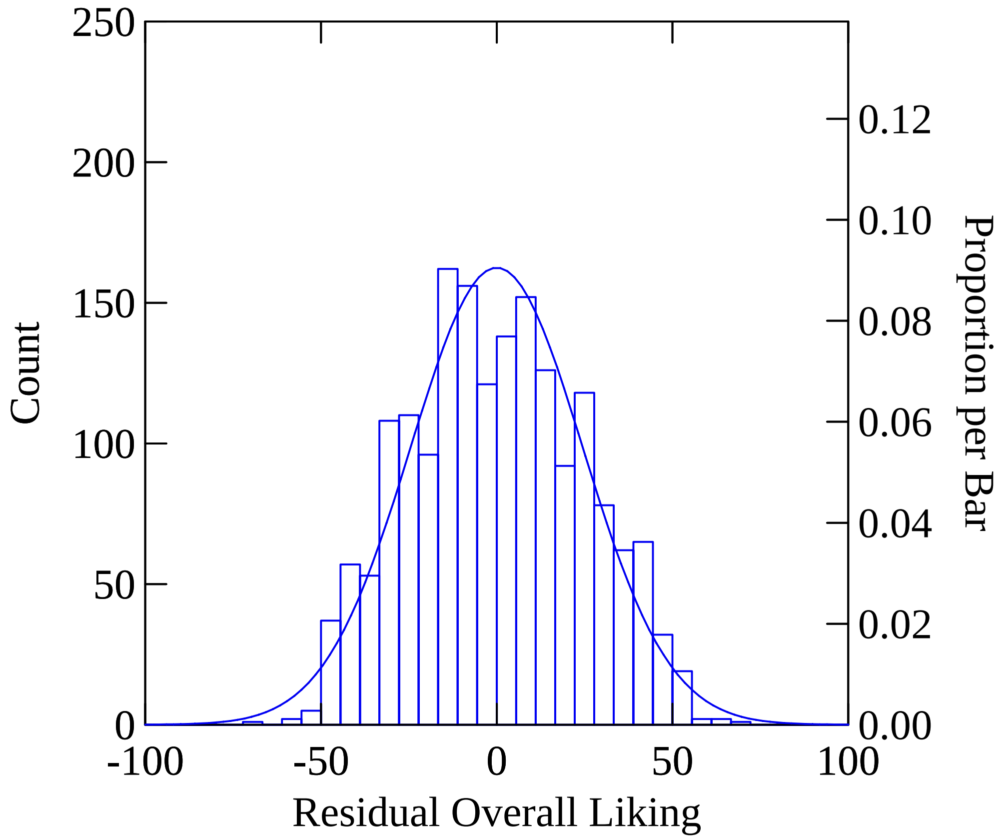
**22.3 Figure 3. Frequency distributions of overall liking classified by a 5 point eating quality category.**



**22.4 Figure 4. Frequency distributions of overall liking classified by 3 point eating quality category.**



**22.5 Figure 5: Histogram of the residual frequency distribution for overall liking for grilling for lambs and yearlings. The distribution is significantly (P<0.01) kurtotic.**



## 22.6 Table 1: Number of consumer responses by animal category and cooking method.

| Animal Category | Grill | Roast | Stir Fry | SC2 |
|---|---|---|---|---|
| Ewe | 1800 | 1560 | 600 | 120 |
| Yearling | 1800 | 1560 | 600 | 120 |
| Lamb | 1800 | 1560 | 600 | 120 |

## 22.7 Table 2: Correlations between each of the sensory variables measured by a consumer.

| | Smell | Tender | Juicy | Flavour | Overall Liking |
|---|---|---|---|---|---|
| Smell | 1.0 | | | | |
| Tender | 0.47 | 1.0 | | | |
| Juicy | 0.48 | 0.77 | 1.0 | | |
| Flavour | 0.59 | 0.71 | 0.71 | 1.0 | |
| Overall Liking | 0.57 | 0.79 | 0.75 | 0.92 | 1.0 |

## 22.8 Table 3: The least squares means for lambs and yearlings for cuts ranked from least desirable to most desirable for grilling.

| Lambs | Lambs | Yearlings | Yearlings |
|---|---|---|---|
| Cuts | Average Overall Liking | Cuts | Average Overall Liking |
| Topside Steaks | $49.2^{1}$ | Forequarter Chops | $50.6^{1}$ |
| Forequarter Shoulder Chops | $57.9^{12}$ | Topside Steaks | $57.8^{12}$ |
| Round Steaks | $60.4^{23}$ | Forequarter B Chops | $60.6^{23}$ |
| Forequarter Chops | $61.5^{234}$ | Forequarter Shoulder Chops | $60.6^{23}$ |
| Forequarter B Chops | $65.4^{234}$ | Round Steaks | $66.2^{234}$ |
| Eye of loin steak | $67.1^{34}$ | Eye of loin steak | $69.3^{34}$ |
| Loin Noisettes | $70.8^{4}$ | Chump Chops | $70.3^{34}$ |
| Chump Chops | $72.5^{45}$ | Shortloin Chops | $70.9^{45}$ |
| Tenderloin | $72.7^{5}$ | Loin Noisettes | $73.2^{456}$ |
| Shortloin Chops | $74.0^{5}$ | Cutlets cap on | $77.2^{56}$ |
| Cutlets _DNFT | $78.5^{56}$ | Cutlets _DNFT | $78.5^{56}$ |
| Cutlets cap on | $82.7^{6}$ | Tenderloin | $84.0^{6}$ |
| SE ± | 2.14 | | 2.10 |

Estimates with the same subscript number are not significantly different from each other (P > 0.05).

## 22.9 Table 4: Regression coefficients and residual variance for lambs and yearlings for smell, tender juicy and flavour on overall liking for each cut in the grill method of cooking.

| Lamb and Yearling. Grill | | | | | | |
|---|---|---|---|---|---|---|
| Cut | Intercept | Smell | Tender | Juicy | Flavour | Residual Standard Deviation |
| Forequarter Shoulder Chops | -0.61 | - | 0.14 | 0.12 | 0.77 | 8.9 |
| Forequarter Chops | -1.31 | - | 0.23 | - | 0.79 | 11.2 |
| Forequarter B Chops | -5.88 | - | 0.23 | 0.15 | 0.75 | 10.4 |
| Chump Chops | -5.68 | 0.04 | 0.24 | 0.04 | 0.75 | 8.4 |
| Topside Steaks | 1.38 | - | 0.19 | 0.07 | 0.74 | 9.7 |
| Loin Noisettes | -4.58 | - | 0.26 | 0.07 | 0.74 | 7.9 |
| Shortloin Chops | -5.43 | - | 0.16 | 0.04 | 0.84 | 10.6 |
| Round Steaks | -1.89 | 0.08 | 0.11 | 0.09 | 0.76 | 7.9 |
| Cutlets _DNFT | -0.79 | 0.11 | 0.19 | 0.05 | 0.69 | 7.4 |
| Cutlets cap on | 2.42 | 0.07 | 0.21 | 0.07 | 0.64 | 6.9 |
| Eye of loin steak | 0.99 | 0.01 | 0.21 | 0.13 | 0.65 | 7.5 |
| Tenderloin | 2.61 | - | 0.19 | 0.08 | 0.72 | 7.7 |

## 22.10 Table 5: The least squares means for lambs and yearlings for cuts ranked from least desirable to most desirable for roasting.

| Lambs<br>Cut | Lambs<br>Average Overall Liking | Yearlings<br>Cut | Yearlings<br>Average Overall Liking |
|---|---|---|---|
| Topside Roast | $48.2^{1}$ | Topside Roast | $51.3^{1}$ |
| Oyster Cut Roast | $50.7^{12}$ | Forequarter Roast | $55.4^{12}$ |
| Round Roast | $54.0^{123}$ | Easy - carve Leg | $56.6^{12}$ |
| Forequarter Shoulder Roast | $59.4^{234}$ | Forequarter Roast(DN) | $57.6^{12}$ |
| Forequarter Roast(DN) | $61.0^{345}$ | Round Roast | $57.8^{12}$ |
| Easy - carve Leg | $61.6^{345}$ | Forequarter Shoulder Roast | $59.6^{12}$ |
| Forequarter Roast | $65.3^{45}$ | Oyster Cut Roast | $60.1^{12}$ |
| Leg Roast Bone - in | $65.5^{45}$ | Leg Roast Bone - in | $61.6^{2}$ |
| Rump Roast cap on | $65.6^{456}$ | Rump Roast cap on | $67.7^{3}$ |
| DN Rump Roast | $70.6^{56}$ | Shortloin Roast | $68.0^{3}$ |
| Shortloin Roast | $75.3^{6}$ | DN Rump Roast | $72.4^{3}$ |
| Rack Roast cap on | $79.5^{7}$ | Rack Roast cap on | $75.1^{3}$ |
| Rack Roast cap off | $83.3^{7}$ | Rack Roast cap off | $80.9^{3}$ |
| SE ± | 2.06 | | 2.12 |

Estimates with the same subscript number are not significantly different from each other ($P > 0.05$).

### 22.11 Table 6: Regression coefficients and residual variance for lambs and yearlings for smell, tender juicy and flavour on overall liking for each cut in the roast method of cooking.

| Cut | Intercept | Smell | Tender | Juicy | Flavour | Residual Standard Deviation |
|---|---|---|---|---|---|---|
| Topside Roast | -2.45 | 0.07 | 0.18 | 0.20 | 0.59 | 9.5 |
| Forequarter Roast | -1.59 | - | 0.14 | 0.20 | 0.68 | 8.3 |
| Oyster Cut Roast | -2.62 | - | 0.15 | 0.20 | 0.67 | 8.8 |
| Forequarter Roast(DN) | -2.10 | 0.04 | 0.17 | 0.12 | 0.70 | 7.6 |
| Easy - carve Leg | -1.78 | 0.04 | 0.22 | 0.14 | 0.64 | 7.9 |
| Forequarter Shoulder Roast | -0.41 | 0.07 | 0.24 | 0.11 | 0.58 | 7.8 |
| Shortloin Roast | -2.28 | 0.05 | 0.13 | 0.13 | 0.74 | 6.2 |
| Round Roast | 0.07 | - | 0.28 | 0.11 | 0.61 | 7.8 |
| Rump Roast cap on | 2.10 | 0.05 | 0.13 | 0.10 | 0.71 | 7.9 |
| Rack Roast cap on | 2.31 | 0.05 | 0.07 | 0.10 | 0.78 | 7.4 |
| DN Rump Roast | 1.51 | - | - | 0.15 | 0.79 | 7.8 |
| Leg Roast Bone - in | 2.77 | - | 0.24 | 0.10 | 0.67 | 7.8 |
| Rack Roast cap off | 4.09 | 0.02 | 0.11 | 0.07 | 0.77 | 5.3 |

### 22.12 Table 7: The least squares means for lambs and yearlings for cuts ranked from least desirable to most desirable for stir fry.

| Lamb Cut | Lamb Average Overall Liking | Yearling Cut | Yearling Average Overall Liking |
|---|---|---|---|
| Topside Strips | $59.8^{1}$ | Topside Strips | $56.0^{1}$ |
| Round Strips | $62.4^{12}$ | Oyster Cut Strips | $60.8^{12}$ |
| Silverside Strips | $63.1^{12}$ | Silverside Strips | $61.5^{12}$ |
| Oyster Cut Strips | $67.1^{12}$ | Round Strips | $63.5^{2}$ |
| Eye of loin strips | $69.7^{2}$ | Eye of loin strips | $67.2^{2}$ |
| SE ± | 2.10 | | 1.96 |

Estimates with the same subscript number are not significantly different from each other (P > 0.05).

### 22.13 Table 8: Regression coefficients and residual variance for lambs and yearlings for smell, tender juicy and flavour on overall liking for each cut in the stir fry method of cooking.

| Cut | Intercept | Smell | Tender | Juicy | Flavour | Residual Standard Deviation |
|---|---|---|---|---|---|---|
| Oyster Cut Strips | -14.25 | - | - | 0.56 | 0.64 | 2.9 |
| Round Strips | -15.62 | 0.17 | - | 0.42 | 0.66 | 2.4 |
| Topside Strips | -5.74 | - | - | - | 1.09 | 2.5 |
| Eye of loin strips | 4.93 | - | - | 0.29 | 0.67 | 2.2 |
| Silverside Strips | 0.52 | - | 0.17 | 0.22 | 0.62 | 2.1 |

## 22.14 Table 9: The least squares means for lambs and yearlings for cuts ranked from least desirable to most desirable for slow wet cooking

| Lamb | Lamb | Yearling | Yearling |
|---|---|---|---|
| Cut | Average Overall Liking | Cut | Average Overall Liking |
| Hindshank Casserole | 52.3 | Hindshank Casserole | 44.7 |
| Fore Shank | 55.4 | Fore Shank | 53.5 |
| SE ± | 3.35 | | 3.59 |

There are no significant differences

## 22.15 Table 10: Regression coefficients and residual variance for lambs and yearlings for smell, tender juicy and flavour on overall liking for each cut in the slow wet cook method of cooking.

| Cut | Intercept | Smell | Tender | Juicy | Flavour | Residual Standard Deviation |
|---|---|---|---|---|---|---|
| Hindshank Casserole | 4.39 | - | - | - | 0.93 | 3.0 |
| Fore Shank | -4.26 | 0.17 | - | 0.26 | 0.61 | 1.8 |

## 22.16 Table 11: The least squares means for ewes for cuts ranked from least desirable to most desirable for grilling

| Cut | Average Overall Liking |
|---|---|
| Forequarter B Chops | $31.3^{1}$ |
| Forequarter Shoulder Chops | $34.9^{1}$ |
| Forequarter Chops | $35.7^{12}$ |
| Topside Steaks | $44.5^{23}$ |
| Shortloin Chops | $45.1^{23}$ |
| Chump Chops | $45.5^{234}$ |
| Round Steaks | $46.1^{34}$ |
| Loin Noisettes | $46.6^{34}$ |
| Eye of loin steak | $49.6^{34}$ |
| Cutlets _DNFT | $50.3^{34}$ |
| Cutlets cap on | $54.3^{4}$ |
| Tenderloin | $72.7^{5}$ |
| SE ± | 2.25 |

Estimates with the same subscript number are not significantly different from each other ($P > 0.05$)

### 22.17 Table 12: Regression coefficients and residual variance for ewes for smell, tender juicy and flavour on overall liking for each cut in the grill method of cooking.

| Cut | Intercept | Smell | Tender | Juicy | Flavour | Residual Standard Deviation |
|---|---|---|---|---|---|---|
| Forequarter B Chops | -7.61 | - | 0.36 | - | 0.48 | 13.1 |
| Forequarter Chops | 0.58 | 0.10 | 0.24 | - | 0.64 | 13.3 |
| Forequarter Shoulder Chops | 0.50 | - | 0.28 | 0.02 | 0.71 | 11.4 |
| Chump Chops | -9.10 | 0.12 | 0.27 | 0.07 | 0.61 | 11.5 |
| Shortloin Chops | -1.34 | - | 0.18 | 0.16 | 0.61 | 11.2 |
| Cutlets _DNFT | -3.29 | - | 0.27 | - | 0.65 | 8.5 |
| Loin Noisettes | 3.07 | - | 0.20 | - | 0.73 | 9.6 |
| Cutlets cap on | 1.62 | - | 0.24 | 0.17 | 0.62 | 9.6 |
| Topside Steaks | 2.90 | - | 0.35 | - | 0.68 | 10.3 |
| Tenderloin | 0.11 | 0.08 | - | - | 0.84 | 8.3 |
| Eye of loin steak | -0.82 | - | 0.28 | 0.06 | 0.64 | 9.8 |
| Round Steaks | -0.37 | - | 0.26 | - | 0.68 | 8.2 |

## 22.18 Table 13: The least squares means for ewes for cuts ranked from least desirable to most desirable for roasting.

| Cut | Average Overall Liking |
|---|---|
| Oyster Cut Roast | $28.3^{1}$ |
| Topside Roast | $31.6^{12}$ |
| Easy - carve Leg | $37.8^{12}$ |
| Forequarter Roast(DN) | $39.1^{2}$ |
| Forequarter Shoulder Roast | $40.1^{2}$ |
| Forequarter Roast | $40.1^{2}$ |
| DN Rump Roast | $40.7^{23}$ |
| Round Roast | $45.2^{23}$ |
| Leg Roast Bone - in | $45.6^{23}$ |
| Rump Roast cap on | $49.1^{23}$ |
| Shortloin Roast | $51.0^{3}$ |
| Rack Roast cap off | $51.1^{3}$ |
| Rack Roast cap on | $55.8^{3}$ |
| SE ± | 2.28 |

Estimates with the same subscript number are not significantly different from each other (P > 0.05)

## 22.19 Table 14: Regression coefficients and residual variance for ewes for smell, tender juicy and flavour on overall liking for each cut in the roast method of cooking.

| Cut | Intercept | Smell | Tender | Juicy | Flavour | Residual Standard Deviation |
|---|---|---|---|---|---|---|
| Rack Roast cap on | -3.16 | - | 0.16 | 0.19 | 0.70 | 9.8 |
| Oyster Cut Roast | -0.34 | - | 0.25 | 0.07 | 0.68 | 6.8 |
| Easy - carve Leg | -5.65 | 0.13 | 0.20 | 0.22 | 0.54 | 7.7 |
| Rack Roast cap off | 2.82 | - | 0.23 | 0.23 | 0.59 | 11.2 |
| Rump Roast cap on | 0.28 | - | 0.14 | 0.22 | 0.65 | 9.4 |
| Forequarter Roast | -1.45 | - | 0.25 | 0.12 | 0.62 | 9.3 |
| Shortloin Roast | -1.87 | - | 0.24 | - | 0.69 | 8.4 |
| Topside Roast | -1.74 | - | 0.10 | 0.22 | 0.68 | 7.6 |
| DN Rump Roast | -1.35 | - | 0.37 | 0.13 | 0.57 | 9.8 |
| Forequarter Roast(DN) | 0.28 | - | 0.14 | 0.22 | 0.65 | 9.4 |
| Round Roast | 1.36 | - | 0.16 | 0.11 | 0.75 | 9.8 |
| Forequarter Shoulder Roast | -1.81 | - | 0.19 | 0.19 | 0.65 | 8.6 |
| Leg Roast Bone - in | 2.74 | - | 0.20 | - | 0.65 | 10.6 |

### 22.20 Table 15: The least squares means for ewes for cuts ranked from least desirable to most desirable for stir fry.

| Cut | Average Overall Liking |
|---|---|
| Oyster Cut Strips | $43.8^{1}$ |
| Topside Strips | $48.2^{1}$ |
| Round Strips | $48.4^{1}$ |
| Silverside Strips | $49.7^{1}$ |
| Eye of loin Strips | $61.1^{2}$ |
| SE ± | 2.20 |

Estimates with the same subscript number are not significantly different from each other (P > 0.05)

### 22.21 Table 16: Regression coefficients and residual variance for ewes for smell, tender juicy and flavour on overall liking for each cut in the stir fry method of cooking.

| Cut | Intercept | Smell | Tender | Juicy | Flavour | Residual Standard Deviation |
|---|---|---|---|---|---|---|
| Oyster Cut Strips | -4.26 | - | 0.29 | - | 0.70 | 9.4 |
| Silverside Strips | -5.31 | 0.09 | 0.28 | - | 0.63 | 9.2 |
| Topside Strips | -4.31 | 0.10 | 0.19 | 0.16 | 0.60 | 8.8 |
| Round Strips | -2.89 | - | 0.32 | 0.11 | 0.61 | 9.5 |
| Eye of loin Strip | -0.52 | 0.11 | 0.16 | 0.14 | 0.63 | 8.2 |

### 22.22 Table 17: The least squares means for ewes for cuts ranked from least desirable to most desirable for slow wet cooking

| Cut | Average Overall Liking |
|---|---|
| Fore Shank | $18.7^{1}$ |
| Hindshank Casserole | $33.9^{2}$ |
| SE ± | 3.12 |

Estimates with the same subscript number are not significantly different from each other (P > 0.05)

### 22.23 Table 18: Regression coefficients and residual variance for ewes for smell, tender juicy and flavour on overall liking for each cut in the stir fry method of cooking.

| Cut | Intercept | Smell | Tender | Juicy | Flavour | Residual Standard Deviation |
|---|---|---|---|---|---|---|
| Fore Shank | -1.24 | - | - | - | 0.75 | 8.5 |
| Hindshank Casserole | 1.59 | - | - | 0.24 | 0.77 | 9.9 |

### 22.24 Table 19: A comparison of the regression coefficients by animal category and cooking method for overall liking on smell, tender, juicy and flavour for cuts with fat on and cuts denuded of fat.

**Lambs and Yearlings**
**Grill**

| Cut | Intercept | Smell | Tender | Juicy | Flavour | Residual Standard Deviation |
|---|---|---|---|---|---|---|
| Cutlets _DNFT | -0.79 | 0.11 | 0.19 | 0.05 | 0.69 | 7.4 |
| Cutlets cap on | 2.42 | 0.07 | 0.21 | 0.07 | 0.64 | 6.9 |

**Roast**

| Cut | Intercept | Smell | Tender | Juicy | Flavour | Residual Standard Deviation |
|---|---|---|---|---|---|---|
| Forequarter Roast | -1.59 | - | 0.14 | 0.20 | 0.68 | 8.3 |
| Forequarter Roast(DN) | 4.09 | 0.02 | 0.11 | 0.07 | 0.77 | 5.3 |

**Ewes**
**Grill**

| Cut | Intercept | Smell | Tender | Juicy | Flavour | Residual Standard Deviation |
|---|---|---|---|---|---|---|
| Cutlets _DNFT | -3.29 | - | 0.27 | - | 0.65 | 8.5 |
| Cutlets cap on | 1.62 | - | 0.24 | 0.17 | 0.62 | 9.6 |

**Roast**

| Cut | Intercept | Smell | Tender | Juicy | Flavour | Residual Standard Deviation |
|---|---|---|---|---|---|---|
| Forequarter Roast | -1.45 | - | 0.25 | 0.12 | 0.62 | 9.3 |
| Forequarter Roast(DN) | -0.01 | - | 0.21 | 0.16 | 0.59 | 10.2 |
| | | | | | | |
| Rack Roast cap on | -3.16 | - | 0.17 | 0.19 | 0.70 | 9.8 |
| Rack Roast cap off | 2.82 | - | 0.23 | 0.23 | 0.59 | 11.2 |
| | | | | | | |
| DN Rump Roast | -1.35 | - | 0.37 | 0.13 | 0.57 | 9.6 |
| Rump Roast cap on | 0.28 | - | 0.14 | 0.22 | 0.65 | 9.4 |
| | | | | | | |
| Eye of Loin Steaks | -0.16 | - | 0.28 | 0.06 | 0.65 | 9.56 |
| Loin Noisettes | 3.07 | - | 0.19 | - | 0.73 | 9.5 |

### 22.25 Table 20. Discrimination of a cut into one of 3 eating quality categories using overall liking as the discrimination variable.

| Animal category | Cooking | Lower bound | Upper bound | Failure rate for 3 (%) | Failure rate for 4 (%) |
|---|---|---|---|---|---|
| Lamb | Grill | 46 | 74 | 16 | 12 |
| | Roast | 45 | 73 | 17 | 15 |
| | Stir Fry | 47 | 72 | 16 | 19 |
| | Slow wet cook | 42 | 69 | 26 | 17 |
| | | | | | |
| Yearling | Grill | 46 | 75 | 12 | 15 |
| | Roast | 44 | 72 | 14 | 17 |
| | Stir Fry | 46 | 71 | 16 | 21 |
| | Slow wet cook | 38 | 68 | 12 | 19 |
| | | | | | |
| Ewe | Grill | 43 | 71 | 16 | 17 |
| | Roast | 41 | 69 | 18 | 19 |
| | Stir Fry | 43 | 70 | 12 | 16 |
| | Slow wet cook | 39 | 73 | 6 | 23 |
| | | | | | |
| All | All | 44 | 73 | 15 | 16 |

### 22.26 Table 21. Average overall liking and expected failure rates for each of the lamb cuts in the grill method of cooking

| Cut | Overall liking | Expected Failure (%) | Expected excellent (%) |
|---|---|---|---|
| Topside steak | 49.2 | 30 | 18 |
| Forequarter shoulder chops | 57.8 | 20 | 26 |
| Round steak | 60.4 | 17 | 36 |
| Shoulder chops | 61.5 | 16 | 33 |
| Forequarter chops | 61.5 | 16 | 33 |
| Forequarter B chops | 65.5 | 13 | 39 |
| Eye of loin steak | 67.1 | 12 | 45 |
| Loin noisettes | 70.8 | 10 | 50 |
| Chump chops | 72.5 | 9 | 52 |
| Tenderloin | 72.7 | 9 | 53 |
| Shortloin chops | 74.0 | 8 | 54 |
| Cutlets denuded | 78.5 | 6 | 60 |
| Cutlets cap on | 82.7 | 5 | 65 |
| SE ± | 2.14 | | |

### 22.27 Table 22. Average overall liking and expected failure rates for each of the lamb cuts in the roast method of cooking

| Cut | Overall liking | Expected Failure (%) | Expected excellent (%) |
|---|---|---|---|
| Topside roast | 48.2 | 29 | 18 |
| Oyster roast | 50.7 | 26 | 21 |
| Round roast | 54.0 | 22 | 26 |
| Forequarter shoulder | 59.4 | 17 | 33 |
| Forequarter roast DN | 61.0 | 16 | 35 |
| Easy-carve leg | 61.6 | 15 | 36 |
| Forequarter roast | 65.3 | 12 | 41 |
| Rump roast DN | 65.6 | 12 | 41 |
| Leg roast bone in | 65.6 | 12 | 41 |
| Rump roast | 70.6 | 9 | 48 |
| Shortloin roast | 75.3 | 7 | 54 |
| Rack roast cap on | 79.6 | 5 | 59 |
| Rack denuded | 83.3 | 4 | 64 |
| SE ± | 2.06 | | |

### 22.28 Table 23. Average overall liking and expected failure rates for each of the lamb cuts in the stir fry method of cooking

| Cut | Overall liking | Expected Failure (%) | Expected excellent (%) |
|---|---|---|---|
| Topside steak | 59.8 | 17 | 36 |
| Round steak | 62.4 | 15 | 39 |
| Silverside strip | 63.1 | 14 | 40 |
| Oyster strips | 67.1 | 12 | 45 |
| Eye of loin steak | 69.7 | 10 | 49 |
| SE ± | 2.10 | | |

### 22.29 Table 24. Average overall liking and expected failure rates for each of the lamb cuts in the slow wet cook method of cooking

| Cut | Overall liking | Expected Failure (%) | Expected excellent (%) |
|---|---|---|---|
| | | Individual | Individual |
| Fore shank casserole | 52.3 | 25 | 23 |
| Hindshank casserole | 55.4 | 22 | 26 |
| SE ± | 3.35 | | |

## 22.30 Table 25. Average overall liking and expected failure rates for each of the Yearling cuts in the grill method of cooking

| Cut | Overall liking | Expected Failure (%) | Expected excellent (%) |
|---|---|---|---|
| Forequarter chops | 50.6 | 29 | 22 |
| Topside steak | 57.8 | 21 | 32 |
| Forequarter shoulder chops | 60.6 | 18 | 35 |
| Forequarter B chops | 60.6 | 18 | 35 |
| Round steak | 66.3 | 13 | 43 |
| Eye of loin steak | 69.4 | 11 | 47 |
| Chump chops | 70.2 | 11 | 48 |
| Shortloin chops | 70.9 | 10 | 49 |
| Loin noisettes | 73.2 | 9 | 52 |
| Cutlets cap on | 77.2 | 7 | 57 |
| Cutlets denuded | 78.5 | 6 | 59 |
| Tenderloin | 84.0 | 4 | 65 |
| SE ± | 2.10 | | |

## 22.31 Table 26. Average overall liking and expected failure rates for each of the Yearling cuts in the roast method of cooking

| Cut | Overall liking | Expected Failure (%) | Expected excellent (%) |
|---|---|---|---|
| Topside roast | 51.2 | 32 | 21 |
| Forequarter roast | 55.3 | 27 | 27 |
| Easy-carve leg | 56.6 | 25 | 28 |
| Forequarter roast DN | 57.6 | 24 | 30 |
| Round roast | 57.8 | 24 | 30 |
| Forequarter shoulder | 59.8 | 22 | 33 |
| Oyster roast | 60.1 | 21 | 33 |
| Leg roast bone in | 61.6 | 20 | 35 |
| Rump roast DN | 67.8 | 15 | 44 |
| Shortloin roast | 68.0 | 14 | 44 |
| Rump roast | 72.4 | 11 | 50 |
| Rack roast cap on | 75.0 | 10 | 53 |
| Rack roast denuded | 81.0 | 7 | 61 |
| SE ± | 2.12 | | |

## 22.32 Table 27. Average overall liking and expected failure rates for each of the Yearling cuts in the stir fry method of cooking

| Cut | Overall liking | Expected Failure (%) | Expected excellent (%) |
|---|---|---|---|
| Topside steak | 56.0 | 22 | 30 |
| Oyster strips | 60.8 | 17 | 36 |
| Silverside strip | 61.5 | 17 | 37 |
| Round steak | 63.5 | 15 | 40 |
| Eye of loin steak | 67.3 | 12 | 45 |

## 22.33 Table 28. Average overall liking and expected failure rates for each of the Yearling cuts in the slow wet method of cooking

| Cut | Overall liking | Expected Failure (%) | Expected excellent (%) |
|---|---|---|---|
| Fore shank casserole | 44.7 | 39 | 15 |
| Hindshank casserole | 53.5 | 27 | 25 |

## 22.34 Table 29. Average overall liking and expected failure rates for each of the ewe cuts in the grill method of cooking. Figures in brackets are for a subset of animals with pH < 6 and GR fat > 6mm.

| Cut | Overall liking | Expected Failure (%) | Expected excellent (%) |
|---|---|---|---|
| Forequarter B chops | 31.3 (37) | 63 (61) | 2 |
| Forequarter shoulder chops | 34.9 (40) | 64 (57) | 3 |
| Forequarter chops | 35.7 (40) | 63 (57) | 4 |
| Topside steak | 44.5 (45) | 51 (51) | 10 |
| Shortloin chops | 45.1 (59) | 51 (32) | 11 |
| Chump chops | 45.5 (54) | 51 (38) | 11 |
| Round steak | 46.1 (45) | 49 (51) | 11 |
| Loin noisettes | 46.6 (55) | 42 (37) | 12 |
| Eye of loin steak | 49.6 (54) | 44 (38) | 14 |
| Cutlets denuded | 50.3 (48) | 44 (46) | 16 |
| Cutlets cap on | 54.2 (64) | 38 (26) | 21 |
| Tenderloin | 72.7 (73) | 17 (17) | 46 |

**22.35 Table 30. Average overall liking and expected failure rates for each of the ewe cuts in the roast method of cooking. Figures in brackets are for a subset of animals with pH < 6 and GR fat > 6mm.**

| Cut | Overall liking | Expected Failure (%) | Expected excellent (%) |
|---|---|---|---|
| Oyster roast | 28.3 (26) | 72 (74) | 2 |
| Topside roast | 31.6 (26) | 67 (74) | 3 |
| Easy-carve leg | 37.6 (46) | 59 (49) | 6 |
| Forequarter roast DN | 39.1 (50) | 58 (43) | 7 |
| Forequarter shoulder roast | 40.1 (49) | 57 (45) | 7 |
| Forequarter roast | 40.1 (49) | 57 (45) | 7 |
| Rump roast | 40.7 (48) | 56 (46) | 8 |
| Round roast | 45.2 (40) | 50 (57) | 12 |
| Leg roast bone in | 45.6 (40) | 49 (57) | 12 |
| Rump roast DN | 49.1 (55) | 45 (37) | 16 |
| Rack roast cap off | 51.1 (67) | 42 (23) | 18 |
| Shortloin roast | 51.2 (62) | 42 (28) | 18 |
| Rack roast cap on | 55.8 (61) | 36 (30) | 23 |

**22.36 Table 31. Average overall liking and expected failure rates for each of the ewe cuts in the stir fry method of cooking. Figures in brackets are for a subset of animals with pH < 6 and GR fat > 6mm.**

| Cut | Overall liking | Expected Failure (%) | Expected excellent (%) |
|---|---|---|---|
| Oyster strips | 43.8 (46) | 48 (46) | 11 |
| Topside steak | 48.2 (45) | 43 (47) | 15 |
| Round steak | 48.4 (45) | 43 (47) | 15 |
| Silverside strip | 49.7 (53) | 43 (47) | 17 |
| Eye of loin steak | 61.1 (64) | 26 (23) | 31 |

**22.37 Table 32. Average overall liking and expected failure rates for each of the ewe cuts in the slow wet method of cooking**

| Cut | Overall liking | Expected Failure (%) | Expected excellent (%) |
|---|---|---|---|
| FQ hock | 18.7 | 100 | 0 |
| Hindshank casserole | 33.9 | 94 | 2 |

## 22.38 Table 33. Logit regression coefficients for classification into EQ rating by "overall' score.

| Animal category | Cooking method | EQ rating | Intercept | Slope (overall) |
|---|---|---|---|---|
| Lamb | Grill | 2 | 13.967 | -0.245 |
| | | 3 | 9.003 | -0.124 |
| | Roast | 2 | 14.284 | -0.252 |
| | | 3 | 9.117 | -0.123 |
| | Stir fry | 2 | 12.241 | -0.212 |
| | | 3 | 8.002 | -0.111 |
| | Slow wet cook | 2 | 11.963 | -0.204 |
| | | 3 | 8.308 | -0.111 |
| Yearling | Grill | 2 | 15.098 | -0.267 |
| | | 3 | 9.102 | -0.124 |
| | Roast | 2 | 15.004 | -0.269 |
| | | 3 | 9.501 | -0.128 |
| | Stir fry | 2 | 15.657 | -0.288 |
| | | 3 | 8.551 | -0.117 |
| | Slow wet cook | 2 | 13.039 | -0.243 |
| | | 3 | 7.825 | -0.105 |
| Ewe | Grill | 2 | 16.281 | -0.265 |
| | | 3 | 10.107 | -0.130 |
| | Roast | 2 | 13.529 | -0.222 |
| | | 3 | 8.133 | -0.104 |
| | Stir fry | 2 | 15.979 | -0.272 |
| | | 3 | 9.732 | -0.127 |
| | Slow wet cook | 2 | 17.055 | -0.272 |
| | | 3 | 8.416 | -0.101 |