final report

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The Relative Eating Quality of Individual Muscles in the Ovine Carcase

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EXECUTIVE SUMMARY

This experiment was conducted to establish the protocols and finalise design issues associated with the sensory testing of sheep meats.

Experiment 1.1

A cutting, packing, transport protocol has been written and is attached. This specifies the cutting lines, sample number requirements and packing details for samples to be transported.

In addition the sample preparation protocols have also been written for grill and roast samples. However subsequent analysis of sensory roasts data suggested that treatment effects in the roasted samples were more difficult to detect for roasts than for grills. It is therefore suggested that the roast protocol be reviewed prior to undertaking more testing.

Experiment 1.2

A sensory experiment was undertaken to generate a data set to examine design issues, the potential for indicator cuts and the relationship between sensory and objective samples. The design was aimed at generating variation in palatability by use of different age classes and the use of stimulation.

The design comprised a total of 18 animals allocated to a 2x2 factorial design with 2 age classes (1st cross full mouth ewes and carry over lambs) and 2 stimulation treatments (high voltage stimulation and a non-stimulated control). As part of the tasting protocol consumers were asked to score tenderness, juiciness, flavour strength, flavour like and overall satisfaction of each of the samples.

Design Issues

The current latin square design (which has fixed the total number of samples that are tasted in a pick, ie 108), uses a total of 10 consumers to taste every sample. Given this constraint there was opportunity to examine the effect of both a decrease in the number of tasters per sample with a concomitant increase in the number of samples tested. .

As a preliminary analysis, the homogeneity of consumer score variance within samples was examined for all sensory dimensions. Analysis of the log transformed variances showed that the consumer data for the samples was relatively homogeneous both for the different treatment effects and also between animals, for all sensory dimensions. The magnitude of the within sample variance was similar to sensory scores for beef.

A simulation data set of 10800 tastings was generated based on the variance structure from the grills. This data set was randomly sampled to assess the effect of different design structures, where the total number of tastings per pick was kept constant, but as the number of tastings per sample decreased (from 10 to 2) the number of animals increased (18 to 90). The simulation data set was structured so that it included between animal effects (both fixed and random) and a cross classified effect (ie muscle within animal).

Based on the results of 600 simulations it was concluded that the most efficient design (ie the one with the highest F ratios and therefore the greatest level of significance for cross classified and fixed effects) occurred with a design that contained 10 tastings per sample. The significance of the random animal term changed little over the range of numbers of tastings per sample.

Also on design issues, the effect of clipping outlying consumer scores from the data before meaning to obtained sample scores was examined. Analysis of the lamb data showed that clipping the data reduced the ability to pick up design effects. Therefore it is recommended that in the future lamb sensory data not be clipped.

There was also a design issue in terms of what questions to ask the consumer to score on each sample. The previous MLA Sheep meat eating quality experiment asked a sample of the consumers to score flavour strength, in addition to the normal 4 sensory dimensions (ie tenderness, juiciness, like flavour and overall likeness). A preliminary analysis of this small data did not find any justification for inclusion of the extra sensory dimension in the consumer score sheet. The present data set allowed an analysis of the flavour strength dimension on a larger data set. Our results showed that flavour strength had both the lowest correlation with other sensory dimensions and had the smallest range between rate categories. In addition a discriminant analysis showed that flavour strength contributed little to a linear function to allocate samples to rate categories. Therefore it was recommended that flavour strength be dropped from future the consumer sensory score sheets.

The present data set confirmed the transportability of the weightings for the different sensory dimensions to be combined into an overall palatability score (SEQ). Using the present data the combined SEQ score resulted in 67% correct classification for rate, which was similar to using the four individual sensory dimensions.

Sheep meat consumption tends to vary widely between countries and ethnic groups. Therefore the importance of demographic effects as a potential source of bias in sensory panels was investigated. This analysis concluded that socio economic factors did not appear to be a source of bias for any of the sensory dimensions when prepared by grill or roast techniques. In addition, analysis of consumer sensory traits found large differences between tasters, although even in the presence of these large taster effects, animal effects were highly significant for grills, although less significant for roasts.

Lamb Indicator Cuts for Sensory Testing

Given the high cost of sensory testing and the constraint on muscle size in sheep carcasses the use of indicator cuts was investigated. This problem was investigated using several data sets

(a) The data for the 5 muscles which were both grilled and roasted was used to identify the sub-set of muscles which gave similar discrimination between fixed effects as the full set of 5 muscles. The results showed that the LD was the best indicator cut, followed by the SV (particularly for discrimination on cooking effects). Given the dominance of LD as an indicator muscle this same analysis was re-run with the LD excluded. The results showed that in the absence of the LD the SV was the next best indicator cut.

(b) Data from the 6 muscles that were grilled were also subjected to the same analysis. Again the LD and SV proved to be useful indicator cuts for the age class effect.

(c) Data from the 6 muscles that were roasted were subjected to the discriminant analysis. Because treatment effects were less apparent in the roast data the usefulness of any cuts as indicators was reduced with the LD identified as a useful discriminator of age class effects.

Correlations were calculated as error correlations were calculated on mean sample scores after adjustment for the main design variables. These error correlations between muscles were generally low suggesting that after adjustment for treatment effects changes in one muscle will only effect a small change in other muscles.

The relationship between sensory and objective measurements was examined for the LD muscle. The results showed a curvilinear relationship between peak force and grilled SEQ scores. The relationship between sensory and objective was much weaker for roasted samples.

CONTENTS

1. INTRODUCTION

MLA's Sheepmeat Eating Quality Program sought to investigate the commercial and technical feasibility of implementing Sheepmeat Eating Quality Improvement in the domestic lamb and mutton industry. To provide guidiance for subsequent experimental design in terms of what muscles to sample, the optimal sensory design and the value of objective measurements to predict sensory results, this program aimed to investigate *the relationship between the eating qualities of individual muscles (cuts) in the sheep carcase in terms of sensory and/or objective measurements*.

The experimental design aimed to provide variation in palatability via both the myofibre and connective tissue axes. This allowed examination of the factors which contributed to variation in consumer scores and the relationship between muscles in the carcass over a range of eating qualities. In addition, the value of using a combination of both sensory and objective measurements to describe eating quality in the carcass was investigated.

Objectives

The research under SMEQ.006 was designed to meet 3 objectives, namely:

1. Determine the optimum (minimum) number of consumers required to taste each animal/muscle/cooking sample in sensory analysis; and

2. Adjust the existing consumer protocol for sheepmeats accordingly.

3. Determine the relationship in consumer sensory and objective measurement terms between the eating quality of individual muscles (cuts) in the sheep carcase.

Design

Two separate experiments were undertaken as part of SMEQ.006.

The first (experiment 1.1) was to establish the sample preparation protocols that needed to be followed for subsequent experiments.

Using these protocols the second (experiment 1.2) undertook sensory and objective measurements on a large number of muscles that varied widely in palatability.

1.1 Protocol Development

Methods

This experiment used a small number of carcases to develop the cutting/preparation techniques and identify those muscles most suitable for packing. Carcasses rangd in weight from 18 to 25 kg. Carcasses were halved and broken down to bone-in primals. (this protocol was required for transport of samples in foam boxes).

The primals were then broken down to individual muscles, trimmed of all epimysium and cut into blocks which could be used for grilling, roasting or objective measurements. Previous experimentation had set the limit for a grill at 220g and a roast insert at 150g. The minimum size for an objective measurement was set at 65g.

The work was undertaken at the Cosign Boning Room in Narremburn, Sydney. Using the above constraints sensory samples were trimmed prepared. The results are shown in Table 1 where 'Y' indicates that it was possible to prepare different combinations from a single muscle from one side of the carcass.

Table 1: Options available for preparation of grilling, roasting and objective samples from lamb carcasses over the weight range of 18 to 25 kg

Muscle		18			22			25	
	Grill	Roast	Object	Grill	Roast	Object	Grill	Roast	Object
Longissimus (LD)	Y		Y	Y	Y	Y	Y	Y	Y
		Y	Y		Y	Y		Y	Y
Biceps femoris (BF)	Y		Y	Y		Y	Y		Y
		Y	Y		Y	Y		Y	Y
Gluteus medius (GM)	Y		Y	Y		Y	Y		Y
		Y	Y		Y	Y		Y	Y
Semimembraneous (SM)	Y		Y	Y		Y	Y		Y
		Y	Y		Y	Y		Y	Y
Triceps brachii (TB)			Y	Y		Y	Y		Y
					Y			Y	
Serratus ventralis (SV)	Y		Y	Y		Y	Y		Y
		Y	Y		Y	Y		Y	Y
Rector Femoris (RF)			Y			Y			Y
Vastus lateralis (VL)			Y			Y			Y
Semitendinosus (ST)			Y			Y			Y
Supraspinatus (SS)			Y			Y			Y
Infraspinatus (IS)			Y			Y			Y

The procedures used in the breakdown are detailed in appendix 1. Once muscles were trimmed of epimysium and squared up for preparation of sensory and objective samples it was not possible to get all 3 samples from the one muscle, with the exception of the backstrap (LD). As shown in Table 1 the available options for the BF, GM, SM, and TB muscles were to get either a grill and objective sample, or a roast and objective sample. After trimming a number of smaller muscles (RF, VL, ST, SS and IS) it was only possible to get sufficient sample for preparation of objective blocks.

Conclusion

The protocol for preparation of sensory (roast and grill) and objective samples is outlined in Appendix II.

Because of the small muscle size after trimming it was only possible to prepare grilling or roasting samples from 6 muscles in the body. A further 5 muscles were of sufficient size to prepare objective samples.

1.2 Design issues with sensory testing of sheep meat

Methods

A total of 18 animals were allocated to a 2x2 factorial design where 2 age classes (1st cross full mouth ewes and carry over lambs) and 2 stimulation treatments (high voltage stimulation and a non-stimulated control) were applied. The numbers of animals in each of the cells is shown in Table 2.

Table 2: Numbers of animals in the age x stimulation cells

Age class	Stimulation treatment	
	Stim	No stim
Young	5	5
Old	4	4

Experiment 1.1 indicated that it was not possible to get both roast and grill samples out of the same muscle from one side of the carcass with the exception of the backstrap. By pooling muscles from both sides it was possible to prepare both grilling and roasting samples for a number of muscles, and in many cases obtain objective samples. However due to size restrictions it was not possible to undertake both roasting and grilling on the *M. triceps brachii (TB)* and *M. vastus lateralis (VL)* and therefore one was selected for grilling and one for roasting. As shown in Table 3, samples from 7 sensory muscles were prepared using the grilling and roasting protocols.

Table 3: The design of experiment 1.2. (X indicates where sample collection was attempted from pooling muscles from both sides of the carcass.)

Muscle	Abbrev	Location	Roast	Objective	Grill
M longissimus	LD	FQ/HQ	X	X	X
M. biceps femoris	BF	HQ	X	X	X
M. gluteus medius	GM	HQ	X	X	X
M. semimembraneous	SM	HQ	X	X	X
M. triceps brachii	TB	FQ	X	X	
M. serratus ventralis	SV	FQ	X	X	X
M. adductor	AD	HQ		X	
M. vastus lateralis	VL	HQ		X	X
M. semitendinosus	ST	HQ		X	
M. supraspinatus	SS	FQ		X	
M. infraspinatus	IS	FQ		X	

<u>Slaughter</u>

Slaughter was conducted over 2 days at the DNRE facility at Werribee. Ewes and lambs were slaughtered in a random order and animals that were pre-designated to the stimulation treatment were treated accordingly.

The stimulation treatment comprised a high voltage stimulation unit (800 volts R.M.S. Bidirectional half sinusoidal pulses, pulse frequency 14.3 pulses/sec 10 ms pulse width) applied to the dressed carcase for 60 seconds. The stimulation was applied to a carcass suspended on a gambrel which was insulated from the rail by a plastic insert. Multipoint probes were positioned on either side of the neck with a clamp on the gambrel completing the circuit. Stimulation commenced 22 - 31 minutes after stunning. The applied voltage was 790-810 volts and the current 1.2 - 1.9 amps

For both slaughter days carcasses were held in the chiller overnight. pH/temperature and time were recorded on at least 5 ocassions during the pre- and post rigor period. The site for the pH readings is shown in figure 1.

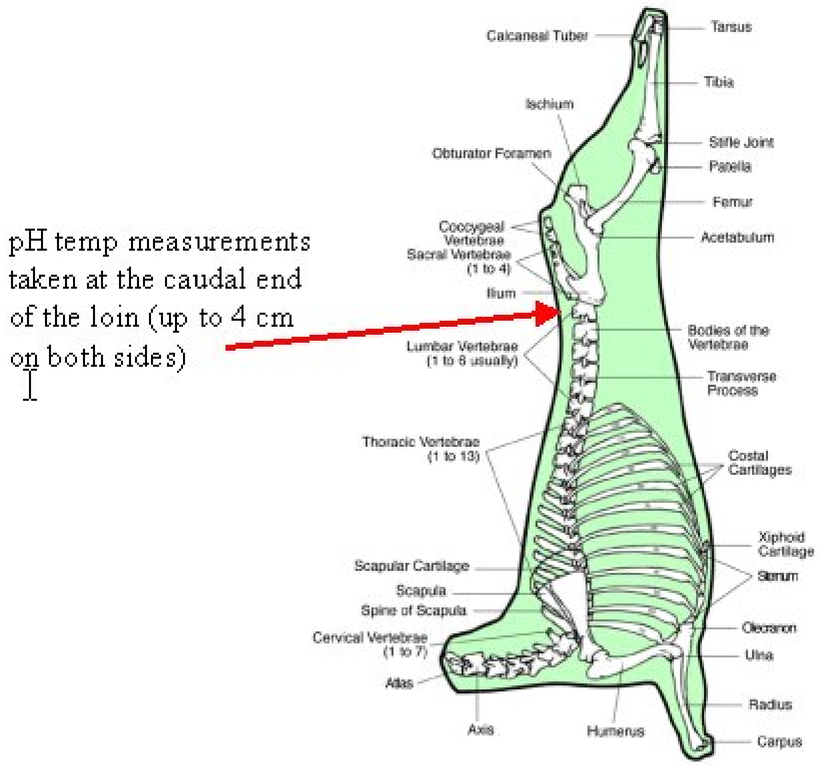

Figure 1: The site for pH measurements on the carcasses during the pre- and post rigor period.

On the day following slaughter carcases were broken, packed and then air-freighted to Sydney for collection by Cosign that afternoon.

At Cosign's Narremburn boning room, sensory samples were prepared on day 3 and samples frozen late that that afternoon (ie effectively 72 hours post-mortem).

On the day of consumer testing, frozen samples were microwaved to bring the temperature from –20 to –5oC. Samples were then allowed to thaw for several hours in foam boxes prior to grilling or roasting sessions.

There were a total of 108 grill and 108 roast samples were prepared. Therefore for the grills there were 108 samples in which each sample was tested by 10 consumers (ie a total of 1080 tastings). These were tasted in 3 picks, each comprising 60 consumers, which were handled in 3 sessions in which each consumer tasted 6 sample, ie 3 picks x 3 sessions x 20 consumers x 6 samples per consumer = 1080 tastings). The roast samples were handled in a similar design, except that the 60 consumers were present at one time to overcome the problem of holding roasts for extended periods.

1.2.1 Results and Discussion

(a) **Means and Variance of Consumer scores**

The mean sensory scores for grill and roast samples from the 4 sub classes are presented in tables 4 and 5.

Table 4: Data statistics for sensory scores grilled samples

Sensory trait	Number	Mean	SD	Minimum	Maximum
TENDER	1080	57.0	26.3	0	100.0
JUICY	1080	56.1	23.3	0	100.0
FLAVSTR	1080	58.6	19.4	3.0	100.0
LIKEFLAV	1080	61.0	22.0	0	100.0
OVERALL	1080	59.3	23.0	0	100.0

Table 5: Data statistics for sensory scores for roasted samples

Sensory trait	Number	Mean	SD	Minimum	Maximum
TENDER	1080	54.4	25.3	0	100.0
JUICY	1080	52.4	23.2	0	100.0
FLAVSTR	1079	55.2	20.6	0	100.0
LIKEFLAV	1080	54.3	21.4	0	100.0
OVERALL	1079	54.4	22.1	0	100.0

The means and variance of both grills sensory scores were of the order of 58 with a standard deviation of approximately 23 units. By comparison the sensory scores for the roasts were lower with a mean score of 54, with a variance of 23 units.

Comparison with the previous experiment shows that the grill scores in this experiment were lower than obtained in the previous sheep meat tasting experiment (ie a mean sensory score of 58 in this experiment, compared with 62 units in SMEQ.005).

(b) **Variation in consumer sensory scores and design implications**

Characteristics of the concumer scores for lamb were examined in a number of ways. Firstly there was a suggestion that lamb consumer scores were less variable than those from beef. This aspect was investigated by examining the homogeneity of within samples scores and whether this varied for treatment.

As a development of this investigation a simulation data set was constructed with similar variance characteristics to the lamb data. Because the number of samples tasted in a pick is constant, this data set was then used to investigate the ramifications of reducing the number of tasters per sample, whilst at the same time increasing the number of animals.

It was appropriate to also test the effect of clipping on lamb sensory scores. Rather than focus on standard errors of sample estimates, this analysis examined the impact of clipping on the F ratio of the treatment effects.

Given that relatively little lamb had been sensory tested using the consumer protocols it was also appropriate to test the relationships between the different sensory dimensions and the robustness of the weightings factors to form the combined meat quality parameter.

Finally this data set also presented the opportunity to examine any bias in lamb sensory scores due to demographic reasons.

Within sample variation in consumer scores

There was a suggestion from the previous lamb eating study that the sensory data for sheep meats was less variable than for beef. If this was the case then there are implications for the design and conduct of future taste panels using sheep meat.

This experiment comprised sheep meat samples which were selected to cover a range of eating qualities by including old sheep and carry over lambs as well as im posing a stimulation treatment treatment (which was designed to create cold shortening in half the carcasses). It could be that tenderness and flavour differences generated by the different treatment effects or between muscles had a variable impact on consumer variance. Therefore this section of the report examined the effect of design variables (stimulation, age class and muscle) on within sample variance.

Methods

Mean sensory dimensions and standard errors were calculated for these 216 sample sub-classes. That is, 108 grills and 108 roasts each derived from 10 consumer scores (ie muscle * animal for both grill and roast results). The variances were logged to normalise the distribution.

<u>*Grills*</u>

The within sample standard errors were examined using a PROC MIXED (SAS 1979), which contained terms for muscle, stimulation and age class and animal as a random effect. This model was used for the following dependent variables: tenderness, juiciness, flavour strength, flavour liking, overall liking and the combined Sheep Eating Quality score (SEQ). SEQ was calculated using the weightings of overall liking 0.4, flavour like 0.3, tenderness 0.2 and juiciness 0.1 (MLA Sheep Eating Quality Report). The F ratios for the within sample variance for the grilled samples are shown in Table 6.

Table 6: F ratios for the effect of stimulation, class, and muscle on sample variance of consumer scores for grilled lamb samples. (adjusted for animal)

Fixed		Sensory dimensions					
Effects	**Df**	**Tend**	**Juicy**	**Flav str**	**Flav like**	**Overall like**	**SEQ**
Stimulation	1,100	**5.82***	4.00	0.02	0.35	2.07	1.58
Age Class	1,100	**9.07****	3.14	0.63	2.97	3.90	3.00
Muscle	5,100	1.22	2.21	1.22	0.61	1.58	0.87

Bolded F ratios are significant at * $P<0.05$, ** $P<0.01$

Table 6 showed that there was a small effect on stimulation and age class on within sample variance, in that the variance of non-stimulated samples was slightly greater than for stimulated samples and the within sample variance from older animals were slighty more variable than for lambs . However there was no effects on the other 4 sensory variables and when combined into a SEQ score there were no effects on within sample varaince.

The random term for animal had no significant effect on the logged variances.

Roasts

A similar analysis to above was undertaken for the roast consumer data, whereby the effect of muscle, stimulation, and age class on the variance of consumer scores for the roast samples was examined. As for the previous analysis the variances were logged prior to GLM analysis.

Results in Table 7 showed that the within sample variances were relatively homogeneous for all fixed effects. There was an effect of muscle on the variance for tenderness score, whereby the *Mm. longissimus (LD)* and *triceps brachii* (TB) had lower variances than other four muscles. However there was no effect of muscle for the other sensory dimensions, and consequently when the 4 sensory dimensions were combined into an eating quality score (SEQ) the muscle effect on variance in tenderness score was diluted and was not significant.

Again the random animal effect had no effect on sample variance.

Table 7: F ratios for the effect of stimulation, class and muscle on sample variance of consumer scores for roasts. (adjusted for animal)

Fixed effects	Df	Sensory dimensions					
		Tend	Juicy	Flav str	Like Flav	Overall like	SEQ
Stim	1,100	3.49	0.26	0.58	0.09	0.64	0.27
Class	1,100	0.98	1.47	0.13	0.59	1.46	0.00
Muscle	5,100	**3.38***	0.14	0.74	0.46	0.80	1.09

Bolded F ratios are significant at $P<0.05$

Conclusion

Design variables (age class, stimulation and muscle) had little effect on the within sample variance of the 10 consumer taster scores for the different sensory dimensions, with the exception of the tenderness score.

When the different sensory dimensions were combined into a sheep meat quality score (SEQ) there were no significant treatment effects on the within sample variance

The effect of reducing the consumer tastings

The lamb sensory data set from experiment SMEQ.006 provided an opportunity to investigate the efficiency of the present sensory design. The report on the first lamb experiment (MLA Sheep Eating Quality Report) suggested that less variation in the sheep meat sensory data.

The present data set provided an opportunity to investigate the efficiency of the present experimental design, by keeping the number of tastings in a pick constant, but decreasing the number of tastings per consumer, whilst at the same time increasing the number of animals included in a pick.

The approach used a simulation data set that had the same variance characteristics as the present data set. For each design combination investigated the number of tastings per sample and the number of animals per treatment were then randomly drawn from the simulated data set times and the F ratios for treatment effects calculated. This procedure was repeated 100 times for each design combination.

Methods

The present design used a total 1080 tastings in a pick. The design options that were investigated are shown in detail in table 8, but in summary included the following;

- a decrease in the number of tastings per sample (from 10 to 2 tastings per sample);
- a subsequent increase in the number of animals, (from 18 to 90 animals)

whilst maintaining 1080 sample tastings per pick.

Table 8: Number of tasting/animal options that were investigated using the simulation runs. The various animal/tasting combinations were constrained to have a total of 1080 tastings for each pick.

Design variables	**Option 1 (10T)**	**Option 1 (9T)**	**Option 1 (6T)**	**Option 1 (5T)**	**Option 1 (4T)**	**Option 1 (2T)**
Number of animals	18	20	30	36	45	90
Number of muscles per carcass	6	6	6	6	6	6
Number of tastings per sample	10	9	6	5	4	2
Total number of tastings/design	1080	1080	1080	1080	1080	1080

To generate the coefficients required for the simulation, a model which contained fixed effects for class and muscle and random effects for animal(age class) was used. The same model was used to estimate the variance components for animal and error.

The data was generated using the coefficients for the fixed effects for class and muscle. The variances for animal (4.18) and error (20.88) were then used to generate a data set of 10,800 tastings (which comprised 180 animals each with 6 muscles and 10 tastings per muscle). The simulated data set was then re-sampled to test the various options listed in table 8. Each animal/taster option was re-sampled and analysed 100 times.

The various data sets were then analysed using a model which contained fixed effects for class and muscle and random effects for animal (class). F ratios were calculated and the mean F ratios are presented in figure 2.

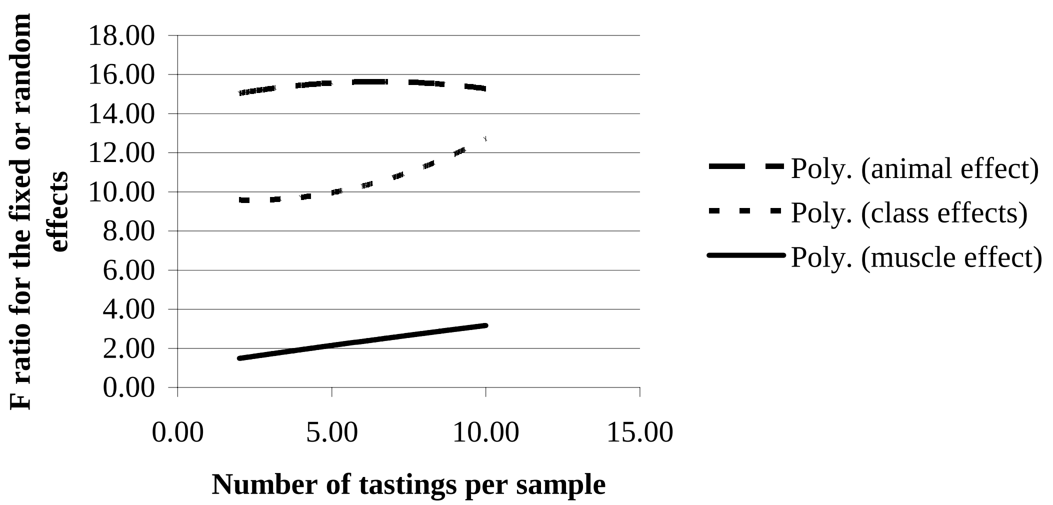

Figure 2: The response surface for the F ratios of treatment effects as a function of the number of tastings per sample assuming a constant number of samples per pick.

The results showed that the F ratio for class and muscle effects had the highest F ratio for a design that comprised 10 tastings per sample and 18 animals. The animal effect had a relatively flat response curve, although there was a suggestion of a point of inflexion in the F ratio at 6 tastings per sample. Decreasing the number of tastings per taster with a corresponding increase in the number of animals resulted in lower F ratios for muscle and age class effects.

Conclusion

- The efficiency of decreasing the number of tastings per sample with a concomitant increase in animal number, whilst maintaining the total number of tastings per pick at 1080 was investigated.
- A simulation data set comprising 180 animals with 10 tastings per sample was generated (ie 10,800 tastings) was established. Each of the design combinations was resampled 100 times and F ratios calculated.
- The results showed that the most efficient design, in terms of the significance of main effects that were on a between animal basis (eg age class) or cross classified (eg muscle) was one that had the greatest number of tastings per sample (10) and fewer animal.

The effect of clipping on within sample variance

Background

The beef MSA protocol clips the consumer sensory data as part of the procedure for calculating final sensory scores for each sample. From the 10 sensory scores, clipping removes the 2 highest and 2 lowest scores to reduce the chance of widely aberrant scores having an undue influence on the mean. (An example of this would be a consumer who scored a sample as a 100 rating, versus consistent values of 20 to 30 from the other 9 who tested a sample, thereby disproportionately distorting the score for that sample)

The beef MSA clipping procedure was developed using data from Trials 5 and 6 in the initial stages of MSA. This data showed that for the 10 consumer scores collected, clipping the top 20 and bottom 20% of scores produced the lowest within sample standard error, thereby providing the most accurate estimate of the animal/muscle sample score. The recommendation from this data set (see Report 479, University of Melbourne) was that clipping the top and bottom 20% (ie a total of 40% of the data) be adopted and its performance be monitored in subsequent consumer testing.

At the lamb eating quality program was commencing it was appropriate that the effect of clipping on the variance and accuracy of sensory data be examined.

The effect on sample variance of clipping lamb sensory scores

The results from different clipping strategies (ie clipping 20 to 80% of the lamb sensory scores for each sample) are shown in Table 9. Both cooking methods showed similar patterns, in that as the proportion of data clipped increased, the standard error of the scores within sample decreased from ca. 6 with the full data set, to ca. 2 if 80% of the data was clipped. These results show that the more consumers clipped from a sample mean, the smaller the standard error of the mean.

Table 9: The effect of clipping on the within sample variance (ie standard error of tasters within sample) for the SEQ scores for lamb grills and roasts

Clipping protocol	Grills	Roasts
10 – 0 (ie the full data set of 10 scores is used)	5.68	5.83
10 – 2 (ie clip top and bottom 10% , ie 20% of the data)	4.20	4.87
10 – 4 (ie clip top and bottom 20%, ie 40% of the data)	3.91	4.14
10 – 6 (ie clip top and bottom 30%, ie 60% of the data)	3.17	3.39
10 – 8 (ie clip top and bottom 40%, ie 80% of the data)	2.26	2.27

The effect of clipping lamb sensory data on the significance of fixed effects

The purpose of clipping was to provide a better estimate of the 'true sample mean' and decrease the chance of aberrant values unduly influencing estimates of the mean. However the problem is that the sample scores have error as they are obtained from the mean of consumer scores.

An alternative way of quantifying whether clipping provided any improvement in the estimate of the mean was to examine the variance accounted for by the fixed effects on **mean sample scores** estimated using a range of clipping protocols (ie the mean SEQ scores for 108 grill and roast samples were estimated using a range of clipping strategies).

Table 10: The effect of clipping strategy on the F ratios for muscle and animal effects on SEQ sample means for lamb grills.

		Clipping Protocol				
	df	**Full**	**10-2**	**10-4**	**10-6**	**10-8**
Muscle	5	**24.01**	**23.08**	**22.13**	**20.75**	**17.99**
Animal	17	**5.43**	**5.12**	**4.63**	**4.10**	**3.76**
Error	85					
RSD		7.234	7.714	8.196	8.799	9.384
R^2		71.42	70.42	69.02	67.11	64.44

All bolded F ratios were significant at $P<0.05$

Table 11: The effect of clipping strategy on the F ratios for muscle and animal effects on SEQ sample means for lamb roasts.

		Clipping Protocol				
	df	**Full**	**10-2**	**10-4**	**10-6**	**10-8**
Muscle	5	**6.14**	**5.75**	**5.71**	**5.74**	**5.86**
Animal	17	**2.04**	**1.84**	**1.67**	**1.61**	**1.54**
Error	85					
RSD		9.023	9.507	9.891	10.074	10.267
R^2		43.56	41.52	40.23	39.87	39.60

Tables 10 and 11 clearly showed that clipping the sensory data decreased the significance of the muscle and animal terms in the models for both grill and roast cooking techniques. In addition the lowest RSDs and the highest coefficients of determination (R^2) were obtained using means derived from the full 10 consumer scores.

These inferred that that the most accurate estimate of the sample mean was obtained using the full 10 consumer scores and clipping reduced the accuracy of this mean.

Perhaps the biggest contrast between the grills and the roast data was the magnitude of the fixed effects for the grill relative to the roast models. F ratios in the grill models were 2 to 4 times higher than F ratios for the same terms in the roast model. Although not exactly the same sub-sets of muscles were tested in both cooking protocols, the inference was that the effects of muscle and animal were more easily discerned by consumers when presented with grilled samples, than if presented with roast samples. **This may be due to either a lower ability of consumers to perceive animal and muscle differences in roast slices, compared with steaks, or alternatively that the roasting procedure (by virtue of application of heat over a longer time) minimises the between sample differences.**

Conclusion

- Clipping outlying consumer scores prior to calculating sample means decreased the standard error of the sample means.
- Comparison of various clipping strategies showed that the significance of animal and muscle effects and the coefficient of determination highest, and the standard error of the model lowest, when sensory scores were not clipped. This inferred that the means obtained from the full data set provided the best estimates of the sample means.
- It is recommended that the lamb sensory data not be clipped and that sample means be estimated using the 10 consumer scores.

Relationship between sensory variables

Correlations between sensory variables

The simple correlations between sensory traits are shown in table 12. With the present data set the flavour strength dimension was scored by all participants, whereas in the previous panels this dimension was only scored for a sample of the taste panels. The correlations followed a similar trend to the previous data set (MLA Sheep Eating Quality Report) in that overall liking had the highest correlation with rate, followed by tenderness and like flavour. The lowest correlations rate and sensory dimensions were for flavour strength and juiciness scores.

The pattern of correlations between the sensory dimensions was similar for the grill and roast data.

These results show that tenderness, like flavour, overall satisfaction were highly correlated with each other and with rate. In contrast, flavour strength, and to a degree juiciness, were less highly correlated with the other sensory variables.

Table 12: Correlations between sensory traits and Rate for grills (above the diagonal) and roast (below the diagonal)

	Tend	Juicy	Flav Str	Like Flav	Overall acceptability	Rate
Tenderness	**1.00**	0.68	0.34	0.63	0.78	0.73
Juiciness	0.42	**1.00**	0.44	0.66	0.71	0.63
Flav strength	0.45	0.37	**1.00**	0.51	0.45	0.37
Like flavour	0.64	0.43	0.60	**1.00**	0.85	0.70
Overall liking	0.75	0.47	0.56	0.90	**1.00**	0.82
Rate	0.71	0.45	0.47	0.75	0.82	**1.00**

Pattern of Consumer Scores by rate category

The pattern of consumer scores by rate category are tabulated in Table 13

Table 13: The means scores, standard deviation and minimum and maximum values for grill and roast sensory dimensions tabulated by rate.

Sensory Dimension	Rate	No	Mean	Stdev	min	Max
Tenderness	2	467	27.6	18.3	0	95
	3	962	52.7	19.4	0	100
	4	501	73.4	16.3	9	100
	5	229	86.7	12.2	7	100
Juiciness	2	467	33.2	19.5	0	100
	3	962	50.8	18.3	0	98
	4	501	68.7	17.1	3	100
	5	229	79.9	15.4	10	98
Flavour	2	467	44.1	21.2	0	100
Strength	3	962	55.7	17.5	3	100
	4	500	64.1	16.5	6	100
	5	229	72.2	17.6	10	100
Like	2	467	33.6	16.5	0	88
Flavour	3	962	55.0	15.9	0	100
	4	501	72.8	12.7	22	100
	5	229	84.7	12.4	24	100
Overall	2	466	27.8	12.8	0	73
Liking	3	962	54.4	13.8	10	100
	4	501	74.3	11.2	27	100
	5	229	87.9	8.0	60	100

Table 13 showed a similar pattern to the previous experiment in that most samples were scored as rate 3, with the smallest category being rate 5. The distribution of scores was also similar to the previous experiment in that the overall means for tenderness, juiciness, like flavour and overall liking were 30, 55, 70 and 85 for ratings 2, 3, 4 and 5 respectively. Flavour strength showed a reduced range of means for 2, 3, 4 and 5 star categories suggesting that flavour strength scores had less ability to contribute to discrimination between the ratings scores.

Discriminant analysis to determine the contribution of the different sensory dimensions to a meat quality score

A discriminant analysis was used to calculate the appropriate weightings for combination of the different sensory dimensions into a combined eating quality score, which discriminated on rate. This analysis was undertaken for roasts and grills separately. Initial analyses indicated that flavour strength and to a lesser extent juiciness contributed little to a linear prediction of rate. As suggested for the earlier report on sheep meat (MLA Sheep Eating Quality Report) flavour strength added nothing to the prediction of rate. Further as little was lost or gained by retention of juiciness in the analysis it was recommended that it be reatined.

Although not tabulated the weightings for the different sensory dimensions were also examined on a within rate basis. The contribution of like flavour and overall liking tended to be inversely related. At the lower eating quality levels (rate 2) flavour liking had a higher contribution to the discriminant function than overall liking, whilst this was reversed at the higher eating quality levels (rate 5). The contribution from tenderness and juiciness appeared to constant at all eating quality levels (ie rates 2, 3, 4 and 5). Although the magnitude of the weightings on like flavour and overall liking appeared changed slightly with rate class there was minimal loss in classification accuracy by fitting the average for the 4 rate classes.

Table 14. The weightings for the combination of individual sensory dimensions to discriminate on rate compared with SEQ weightings from the previous experiment.

	Roasts	Grills	Overall	SEQ
Tenderness	0.21	0.17	0.20	0.2
Juiciness	0.04	0.10	0.06	0.1
Like flavour	0.25	0.20	0.26	0.3
Overall liking	0.50	0.52	0.49	0.4

The efficiency of an SEQ score calculated using the weightings from the MLA Sheep Eating Quality Report was 67.1% correct classification, compared with 67.8% if the four individual dimensions are used. This indicates there is little loss in efficiency using the weightings recommended in the first MLA Sheep Eating Quality Report tested on an independent data set.

These results compare favourably with beef sensory data, where a similar proportion of correct classifications was obtained by use of the MQ4 score compared with individual dimensions.

Conclusion

- Of all the sensory traits, overall liking had the strongest correlation with rate, followed by like flavour and tenderness, with juiciness and flavour strength having the lowest correlation with rate.

- The weightings from the discriminant analysis confirmed the recommendation from the previous sheep meat experiment, in that a sheep eating quality score which provided the best prediction of rate was calculated using the following:

  - 0.4 X Overall liking
  - 0.3 X Like flavour
  - 0.2 X Tenderness
  - X Juiciness

- using an SEQ score calculated using the above weightings to predict rate provided over 67% correct classification, similar to using the individual sensory dimensions.

Demographic and design effects on sensory scores

Background

The initial screening undertaken by Sensory Solutions selected panellists that were between 18 and 55 years, no dentures, ate red meat at least once a week and preferred a medium degree of doneness. In addition to these screening variables, other data on demographic factors were also collected.

The socio-economic factors for consumers participating in the lamb sessions comprised

- Income — level of income (3 categories)
- Postcode — typically 10 to 20 postcodes in any one session
- Age — age (4 categories)
- Gender — male or female
- Occupations — occupation (9 categories)
- Often eat — frequency of eating meat (7 categories)
- Adults — the number of adults in the house (6 categories)
- Children — the number of children in the house (4 categories)
- Appreciation — a statement as to how they enjoy eating meat (4 categories)
- Doneness — preferred degree of doneness (6 categories)

Analysis of MSA beef data indicated that demographic effects had little impact on sensory scores given by consumers. That is, beef CMQ4 scores collected using consumers from say Wollongong were similar to the CMQ4 scores given by consumer on the North Shore of Sydney.

Sheep meat consumption tends to vary widely between countries and ethnic groups. Therefore demographic effects have the potential to be more important for sheep meats than for beef. This analysis examined the importance of these demographic factors on the sensory scores for sheep meat.

Method

The design of the tasting sessions used a latin square design in which 5 samples (each halved and served to 2 consumers) from each animal*muscle class were tested in different sessions and in a different order position.

There were a total of 180 consumers used for each cooking technique. The analysis used a mixed model (SAS) to examine the effect of design and socio-economic factors on the sensory dimensions (tenderness, juiciness, flavour strength, like flavour, overall acceptability and the SEQ score).

The mixed model contained fixed effects for session, order, income, postcode, age, gender, occupations, frequency, No. adults, No. children, meat appreciation, and doneness and random effects for animal and taster nested within session.

Results and discussion

Table 15: Percent probability for the significance of design and demographic effects on sensory dimensions of grilled samples

Factor	Tender	Juicy	Flavour Strength	Flavour Like	Overall Like	SEQ
<u>Design effects</u>						
Muscle	0.0001	0.0001	0.3226	0.0001	0.0001	0.0001
Session	0.9331	0.5790	0.6645	0.7316	0.5674	0.7241
Order	0.0012	0.0556	0.0940	0.0666	0.0033	0.0029
<u>Random effects</u>						
Animal	0.0091	0.0668	0.2736	0.0322	0.0168	0.0144
Taster/session	0.0002	0.0002	0.0001	0.0001	0.0050	0.0001
<u>Demographic effects</u>						
Income	0.3622	0.0700	0.1340	0.3097	0.1412	0.1614
Post code	0.3996	0.0710	0.3355	0.9209	0.7368	0.6307
Age	0.9078	0.6159	0.6678	0.5253	0.4267	0.5485
Gender	0.8673	0.8604	0.1098	0.4779	0.6374	0.6348
Occupation	0.4357	0.1891	0.1353	0.6434	0.2386	0.3607
Frequency	0.3369	0.0036	0.4660	0.2601	0.1601	0.1220
No. Adults	0.9057	0.8927	0.9827	0.7319	0.5640	0.7342
No. Children	0.1574	0.3207	0.8560	0.4660	0.1677	0.1969
Appreciation	0.3359	0.2084	0.1458	0.0504	0.0195	0.0697
Doneness	0.4892	0.2771	0.4836	0.6614	0.0195	0.3706

Bolded percent probabilities are significant

Table 15 showed that for samples cooked as grills, muscle had a significant effect on all sensory dimensions, with the exception of flavour strength. Session effects were not significant, whilst order of presentation significantly affected tenderness, overall liking and the SEQ score.

As expected, taster nested within session was highly significant for all sensory dimensions. Even with the variation between tasters, between animal variation in tenderness and overall liking was large enough to be highly significant., indicating that although consumers were 'noisy' in their scores they were still precise enough to easily discern the between animal variation in sensory scores.

Table 16 Predicted means for the 5 sensory dimensions (tenderness, juiciness, flavour strength, flavour liking, overall satisfaction and the combined SEQ) for tasting order of grilled samples after adjustment for design (muscle, session) demographic effects (income, post code, age, gender, occupation, frequency of eating meat, no. of adults, no. of children, appreciation of meat, doneness) and random (animal and taster(session)) effects

	Sensory dimension					
Tasting order	**Tender**	**Juicy**	**Flav str**	**Flav liking**	**Overall Satisfaction**	**SEQ**
2	50.7	51.9	55.2	57.2	50.7	54.4
3	57.1	54.5	58.1	60.6	57.1	58.7
4	54.3	54.6	58.0	60.2	54.3	57.2
5	57.7	56.8	58.9	61.3	57.7	59.7
6	58.3	57.7	59.9	63.5	58.3	60.7
7	60.3	57.4	60.5	62.3	60.3	61.6
Av se	3.02	2.09	1.69	2.10	3.02	2.21

The predicted means for order of presentation (adjusted for other factors) for grilled lamb samples are shown in Table 16. There was a trend for all dimensions to increase their sensory scores with tasting order. The effect was most significant for tenderness, overall satisfaction and SEQ score, with the increase in order from position 2 to 7 being of the order of 7 to 10 sensory units.

The effect of adjustment for order, session and taster can be seen in the following figure where adjusted means for sample were graphed against raw means. Although there was some variation between adjusted and non-adjusted means the relationship between the two methods was very high with a coefficient of determination of over 90%.

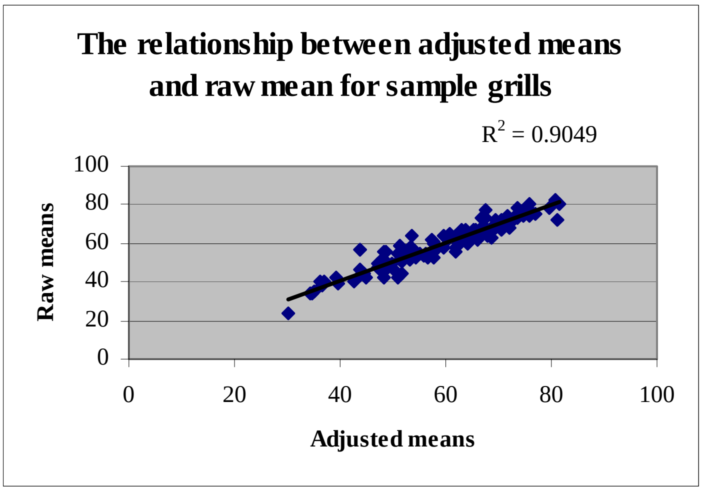

Figure 3: The relationship between raw SEQ scores and SEQ scores adjusted for order.

Demographic effects were noted for their lack of significance on sensory dimensions of grilled lamb samples. The only variable that approached significance was the frequency of eating red meat on juiciness.

Table 17: Percent probability for the significance of design and demographic effects on sensory dimensions of roasted samples

Independent Variables	Tender	Juicy	Flav Str	Flav Like	Overall Satisfaction	SEQ
<u>Design effects</u>						
Muscle	**0.0001**	**0.0001**	0.0475	**0.0001**	**0.0001**	**0.0001**
Session	0.8757	0.6031	0.4750	0.5641	0.3077	0.5817
Order	**-**					
<u>Random effects</u>						
Animal	0.0851	0.0705	0.2427	0.1997	0.1624	0.1089
Taster/session	**0.0001**	**0.0006**	**0.0001**	**0.0013**	**0.0011**	**0.0011**
<u>Demographic</u>						
Income	0.1286	0.5155	0.6524	0.2659	0.2462	0.2069
Post code(session)	0.9846	0.7375	0.3612	0.9880	0.9849	0.9973
Age	0.4830	0.3605	0.8603	0.1826	0.4206	0.3442
Gender	0.2954	0.9465	0.7111	0.7629	0.9035	0.8014
Occupation	0.7374	0.7256	0.3746	0.9353	0.9378	0.9803
Frequency	0.1384	0.2589	**0.0226**	0.1342	0.1434	0.0963
No. Adults	0.2630	0.3873	0.9819	0.8917	0.8708	0.6760
No. Children	0.6496	0.6267	0.1879	0.8757	0.7157	0.8182
Appreciation	**0.0474**	0.6106	0.2739	0.4486	0.2836	0.2157
Doneness	0.7475	0.8742	0.2099	0.6568	0.7904	0.7630

For roasted samples, order effects were confounded with muscle effects, in that each muscle was tasted in the same order by all consumers. . As shown in Table 17 the muscle (and/or order) effect was highly significant for all sensory dimensions of roasted samples, with the exception of flavour strength. As for the grill analysis, session had little effect on sensory dimensions.

Taster nested within session was highly significant for all sensory dimensions. In contrast to the grill results, animal effects were not as significant for the roast data. In table 16 animal approached significance in for tenderness and juiciness (ie $P<0.10$). **This says that when adjusted for other effects, there was no significant difference between animals in consumer scores for roasted samples, whereas the between animal effect was highly significant in grilled samples.** As discussed earlier the lower sensitivity to between animal difference may be due to a reduced ability of consumers to perceive animal differences in roast slices, compared with grilled steaks, or alternatively that the roasting procedure (by virtue of application of heat over a longer time) minimised the between sample differences.

This in combination with earlier results that showed less significant age class, stimulation and muscle effects for roasted compared with grill samples throws doubt on the protocol for roast preparation and we suggest that further work be done to resolve these apparent problems before roasting is used in future experiments.

Postcode was nested within session, since the different sessions drew on consumer from different geographic regions. In accordance with the grill results there was no significant effect of demographic factors on sensory dimensions, with the exception of appreciation category for tenderness and frequency of eating meat for flavour strength score

Conclusion

- Analysis of consumer sensory traits found large differences between tasters. Even in the presence of large taster effects animal effects were highly significant for grills, although less significant for roasts.

- Session effects were not significant.

- Order effects were significant for grills, although the difference in adjusted and unadjusted means was relatively small.

- Socio economic factors did not appear to be a source of bias for any of the sensory dimensions when prepared by grill or roast techniques.

Lamb Indicator Cuts for Sensory Testing

Correlations between muscles

Correlations between muscles were examined at 2 levels. Firstly as simple correlations between the 5 muscles that were grilled and roasted and secondly as error correlations after adjustment for treatment effects. These correlations were not adjusted for treatment variation and in fact would overestimate the relationship within a population. Correlations were not significant for juiciness or flavour strength scores and are not presented in the table.

It is of interest that correlations were moderately high between the BF, GM, LD and SV. This contrasted with the SM muscle, which was not related to other muscles in the carcass. This trend was apparent for all tenderness, flavour like, overall like and the combined SEQ score.

Table 18: Simple correlation matrix for mean scores between muscles. (This data set included all 5 muscles which were grilled and roasted.)

	BF	GM	LD	SM	SV
Tenderness					
BF	1.00				
GM	0.60	1.00			
LD	0.54	0.59	1.00		
SM	0.19	0.01	-0.06	1.00	
SV	0.36	0.41	0.49	0.08	1.00
Flavour like					
BF	1.00				
GM	0.55	1.00			
LD	0.47	0.44	1.00		
SM	0.19	0.16	0.00	1.00	
SV	0.46	0.47	0.31	0.10	1.00
Overall like					
BF	1.00				

	BF	GM	LD	SM	SV
GM	0.53	1.00			
LD	0.36	0.42	1.00		
SM	0.24	0.14	-0.15	1.00	
SV	0.40	0.40	0.32	0.02	1.00
SEQ score					
BF	1.00				
GM	0.56	1.00			
LD	0.48	0.49	1.00		
SM	0.19	0.06	-0.15	1.00	
SV	0.40	0.44	0.38	0.02	1.00

Whereas the simple correlations were an overestimate of the relationship between the various muscles, error correlations were calculated after adjustment for age class, stimulation and day of slaughter effects. The error correlations are shown in table 19. As expected they are generally lower than the simple correlations in table 18.

It is interesting that these results also show that muscles tended to be positively related, with the exception of the SM muscle, which appears unrelated to other muscles in the carcass.

Table 19: Error correlation matrix for tenderness scores of muscles after adjustment for age class, stimulation, day, and cooking effects

	BF	GM	LD	SM	SV
Tenderness					
BF	1.00				
GM	**0.44**	1.00			
LD	0.24	0.29	1.00		
SM	0.19	-0.08	-0.13	1.00	
SV	0.29	0.19	0.17	0.18	1.00
Like flavour					
BF	1.00				
GM	0.35	1.00			
LD	0.18	0.00	1.00		
SM	0.19	0.14	-0.11	1.00	
SV	0.18	0.05	-0.33	-0.01	1.00
Overall like					
BF	1.00				
GM	0.41	1.00			
LD	0.04	0.01	1.00		
SM	0.39	0.111	-0.22	1.00	
SV	0.26	0.11	-0.30	0.04	1.00
SEQ score					
BF	1.00				
GM	0.41	1.00			
LD	0.20	0.10	1.00		
SM	0.31	0.05	-0.18	1.00	
SV	0.23	0.11	-0.21	0.05	1.00

The implications from the correlations between muscles is that to a degree the sensory attributes for muscles within the carcass tend to be positively related, albeit the relationship is not strong for particular muscles. The one result that stands out is that the sensory attributes of the SM muscle appear to be unrelated to other muscles in the body. Therefore when sensory testing different muscles in the carcass it would be important to include a representative muscle from bulk of the carcass (eg LD), along with the SM muscle.

Conclusions

- Correlations between muscles whether as the simple or error correlation showed that muscles within the carcass tended to be positively related in terms of sensory traits, with the exception of the SM muscle.

- The implication of this is that sensory testing should be carried out on several muscles in the carcass. The logical choice would be the LD (to represent the majority of the musculature of the carcass) and the SM (which appears unrelated in terms of sensory traits to other muscles in the carcass).

A multivariate approach to identify indicator cuts

Background

The high cost of sensory testing and the restriction on the size of sheep muscles available for sensory testing make it attractive to identify indicator cuts that could be used to discriminate on eating quality. By definition, good indicator cuts would capture similar treatment effects, which were evident using the full array of muscles.

The present design incorporated variation in tenderness from both myofibre and connective tissue sources. Therefore those muscles which discriminated on age class effects would most likely do so on the basis of connective tissue solubility, whilst those muscles which discriminated on stimulation effects would most likely do so on the basis of myofibre toughness.

Methods

The use of indicator cuts was investigated using a multivariate approach, whereby the fixed effects on the palatability were established and then the subset of muscles that contributed to the discrimination of these effects determined. This was achieved using a step-down discriminant analysis, where partial F ratios described the contribution of the muscle to discrimination of fixed effects. (REG, Gilmour 1989).

This initially involved running models with the full set of muscles, calculating the partial F-ratios and sequentially deleting the muscle with the lowest partial F-ratio (ie those muscles with the lowest discriminatory ability when assessed in the presence of other muscles). The models were then rerun until the smallest significant subset of muscles that provided similar discrimination for treatment effects to the full set of muscles, was identified.

As the first analysis using the five muscles that were grilled and roasted identified the backstrap (LD) as the best single indicator muscle and so the analysis was re-run with the backstrap excluded.

Results and discussion

The initial analyses used a model with fixed effects for age class, stimulation, day of slaughter, cooking technique and all first order interactions. The dependent variable comprised the 5 muscles (*biceps femoris* BF, *gluteus medius* GM, *longissimus dorsi* LD, *semimembraneosus* SM and *serratus ventralis* SV), which had been both grilled and roasted.

Analysis 1: *Using the 5 cuts which were both grilled and roasted*

Multivariate models containing terms for age class, stimulation, day of slaughter and cooking were fitted to the 5 muscles which were both grilled and roasted for the different sensory dimensions. There were no significant treatment effects for the multivariate model for juiciness and flavour strength scores.

The step down discriminate analyses indicated the reduced subset of muscles capable of giving similar separation between treatment effects. In other words, the subset of muscles which could be used as indicator cuts for a particular effects.

Cooking effect

- The step down discriminant analyses showed that the cooking effect could be adequately explained by LD and SV for like flavour, overall satisfaction and SEQ score. The muscle that provided the greatest discrimination between cooking techniques for all significant sensory traits was the SV. This is perhaps not surprising since it is a high connective tissue muscle and so cooking would have a large impact on palatability.

For tenderness score the SV providedthe best descrimination between cooking techniques.

Day effect

- The day effect was only significant for flavour liking and the SEQ score. Generally the LD either alone or in combination with the SV provided the best descrimination of the day effect.

Stimulation effect

- The stimulation effect was only significant only for tenderness, overall satisfaction and SEQ score and even then the significance was only at the $P<0.05$ level. The step down discriminant analyses showed that a combination of the LD and SV muscles or the LD alone provided adequate discrimination for this effect. It was not surprising that the LD was in this sub-set as it is a low connective tissue muscle which is susceptible to cold shortening.

Age class effect

- The age class effect was significant for tenderness, flavour liking, overall satisfaction and SEQ score. The step down discriminant analyses showed that the LD and SV provided adequate descrimination of this effect, with the exception of the tenderness score where the LD and BF provided significant discrimination.

Conclusion

The LD was the best indicator cut to describe treatment effects in the carcass. The next best cut was the SV particularly for discrimination on cooking effects.

Because of the dominating effect of the LD muscle the analysis was re-run excluding the LD. Although not tabulated, these results showed that the SV was the next most important muscle for discrimination between treatment effects with the BF being significant for the age class effect for overall liking and SEQ dimensions.

Table 20: Muscles which had significant partial F ratios for fixed effects of age class, stimulation, day of slaughter and cooking effects from the step down discriminate analysis of 5 muscles in the carcass.

	Muscles				
Fixed effects	**BF**	**GM**	**LD**	**SM**	**SV**
Tenderness					
Age Class	4.9*		12.7**		
Stim			4.7*		
Day					
Cooking					13.7**
Juiciness					
Age Class					
Stim					
Day					
Cooking					
Flavour Strength					
Age Class					
Stim					
Day					
Cooking					
Flavour Liking					
Age Class			14.7**		8.6**
Stim					
Day			7.7*		5.5*
Cooking			13.8***		35.9***
Overall liking					
Age Class			21.4**		8.60**
Stim			4.8*		4.46*
Day					
Cooking			14.6***		22.6***
SEQ score					
Age Class			20.8***		7.2**
Stim			5.07*		5.3*
Day			4.3*		
Cooking			9.8**		22.2***

*, ** and *** were significant at P<0.05, 0.01 and 0,001 respectively.

Analysis 2: ***Using the 5 cuts which were grilled***

A similar step down discriminant analysis was done for the 5 muscles that were grilled. As this data set comprised only 18 records the error degrees of freedom were reduced to 14. Given the low numbers analyses were only conducted on the SEQ score.

Table 21: Muscles which had significant partial F ratios for fixed effects of age class, stimulation, day of slaughter from the step down discriminate analysis of 6 muscles which were grilled.

Treat	BF	GM	LD	SM	SV	TB
Age class			13.4		13.2	
Stim						
Day				6.7	5.0	

This analysis showed that within the muscles that were grilled the LD and SV provided good discrimination of the age class effect. Within the grilled samples none of the muscles provided good discrimination between the stimulation effect. The combination of the SM and SV provided discrimination between the day of slaughter effect, although the magnitude of the F ratios was marginal.

Analysis 2: ***Using the 5 muscles which were roasted***

A step down discriminant analysis was also done for the 5 muscles that were roasted. Again as this data set comprised only 18 records analyses were only conducted on the SEQ score.

Table 22: Muscles which had significant partial F ratios for fixed effects of age class, stimulation, day of slaughter from the step down discriminate analysis of 6 muscles which were roasted.

Treat	BF	GM	LD	SM	SV	VL
Age class			6.2*			
Stim						
Day						

The analysis in Table 22 showed that within the muscle samples that were roasted the LD was the only muscle that provided discrimination between age class effects. This lack of treatment effects within the roasted samples is consistent with the results of previous analyses and highlights the need to critically evaluate this cooking protocol.

Conclusions

- The use of indicator cuts for sensory testing was examined using the 5 muscles which were both roasted and grilled. Not surprisingly the results showed that the indicator cuts varied depending upon the treatment effect and sensory dimension in question.
  - Indicator muscles for the cooking effect on tenderness, flavour liking, overall liking and SEQ score comprised the LD and SV muscles
  - Indicator muscles for the slaughter day effect comprised the sub-set of GM, LD and SM muscles

- Indicator muscles for the stimulation effect comprised the sub-set of LD and SV muscles

- Indicator muscles for the age class effect generally involved the LD in combination with other muscles which varied depending on the sensory trait.

- Within those muscles that were grilled the LD and SV provided good discrimination of the age class effect. Subsets of muscles did not discriminate between stimulation effects.

- Within those muscles that were roasted only the LD provided discrimination of the age class effect. Subsets of muscles did not discriminate between stimulation or day of slaughter effects

- It was concluded that the LD in combination with perhaps the SV provided a subset of muscles which provided good discrimination between age class, stimulation and cooking effects.

Treatment effects on palatability

The grill and roast data sets were combined to assess the impact of treatment effects and their interactions on palatability.

Dependent variables were the 5 sensory dimensions along with the combined SEQ score. The model included terms for age class, stimulation, day of slaughter, muscle and cook, with all first order interactions. When non-significant interactions were removed the final model for SEQ included terms for stimulation, day, age class, muscle, cook, stim*age class, class*muscle and muscle*cook. This model was then fitted to the other sensory dimensions.

The F ratios, RSDs and coefficients of determination (R^2) are presented in table 22. The models for SEQ, overall liking, like flavour and tenderness accounted for a similar proportion of variance, with models for flavour strength and juiciness having much lower coefficients of determination.

The models in Table 22 are an initial attempt to model palatability in sheep meats. The RSD for the SEQ model was of the order of 8 palatability units. In beef the RSD for the final models is of the order of 11 MQ4 units which suggests that it will be possible to develop a model to predict eating quality of lamb with perhaps greater accuracy than has been achieved with beef.

Table 22: F ratios for the effects of stimulation, day, age class, muscle and cooking technique on sensory dimensions

Terms		**Sensory traits**					
		Tend	**Juicy**	**Flv str**	**Like flav**	**Overall**	**SEQ**
Stim	1,193	**6.59**	**3.22**	0.56	**4.41**	**6.63**	**6.85**
Day	1,193	**42.96**	1.91	0.25	**20.58**	**25.54**	**28.19**
Age Class	1,193	**20.17**	**6.53**	**12.04**	**25.72**	**23.60**	**24.14**
Muscle	6,193	**22.05**	**12.65**	2.08	**14.24**	**19.40**	**19.95**
Cook	1,193	**4.09**	**2.43**	**7.58**	**48.41**	**21.09**	**20.84**
Stim*class	1,193	**13.33**	**10.08**	**7.47**	**25.16**	**25.61**	**24.29**

Terms		Sensory traits					
		Tend	Juicy	Flv str	Like flav	Overall	SEQ
Class*muscle	6,193	**4.58**	**2.71**	1.41	**3.51**	**4.58**	**4.58**
Muscle*cook	4,193	**3.52**	1.60	0.63	2.41	**2.89**	**2.94**
RSD		10.40	11.51	7.52	7.13	8.24	7.89
R^2		58.9	39.7	21.7	56.0	57.8	58.7

Bolded F ratios were significant at P<0.05

Table 23: Predicted Means for the muscle*cook, class*muscle and stim*class interactions for SEQ score.

Muscle*cook								
	BF	GM	LD	SM	SV	TB	VL	Av se
Roast	48.1	56.1	59.4	47.2	54.6	58.3	-	
Grill	51.8	61.0	67.4	46.4	65.7	-	59.4	3.7
EWE	44.4	54.6	57.6	48.6	57.2			4.6
LMB	55.5	62.5	69.2	45.0	63.0			
	NS	Stim						
EWE	54.5	52.0						2.2
LMB	55.4	63.7						

The predicted means for the interactions are shown in table 23. The cook*muscle interaction was largely a function of the SM muscle, where roasting and grilling resulted in similar palatability. For all other muscles grilling resulted in a higher palatability than roasting.

The age class*muscle interaction was also due to the SM muscle whereby ewes and lambs had a similar palatability. This contrasts to other muscles, where the same muscles in lambs had a SEQ score 6 to 10 points higher than in the ewes.

These interactions are largely a result of the SM muscle, which is supported by the earlier analysis which showed that there was little correlation between the SM muscle and the other muscles in the carcass.

The predicted means for the age class*stimulation interaction showed that stimulation was only effective in the lambs, having little effect in the ewes. This was surprising as muscles with a range of connective tissue content were sensory tested and it would have been expected that the low connective tissue muscles in the ewes would still have responded to stimulation.

Conclusions

- The SEQ showed significant interactions for muscle*cook, muscle*age class and age class*stimulation.

- The muscle* cook interaction showed that grilling resulted in a higher SEQ score than roasting for all muscles, with the exception of the SM.

- The age class*muscle interaction showed that lambs had a higher SEQ score for all muscles than ewes with the exception of the SM.

- The age class*stimulation interaction showed that stimulation resulted in a higher palatability score in lambs, in contrast to ewes where stimulation had little effect on palatability.

The relationship between sensory and objective measurements

As stated in the project submission the priority for sample collection was for sensory samples. Therefore due to muscle size constaints only the longissimus dorsi (LD) and the semimembranosus (SM) muscles had both sensory (grills and roasts) and objective (shear force) data available. As the roasts were wrapped in muscle from the same carcass there was insufficient sample to collect the planned number of objective samples.

Grills

There were 16 LD and 9 SM samples available for objective measurements. As the SM sample was considered too small it was not included in any analysis.

The relationship between SEQ score for grills and shear force is shown in figure 3.

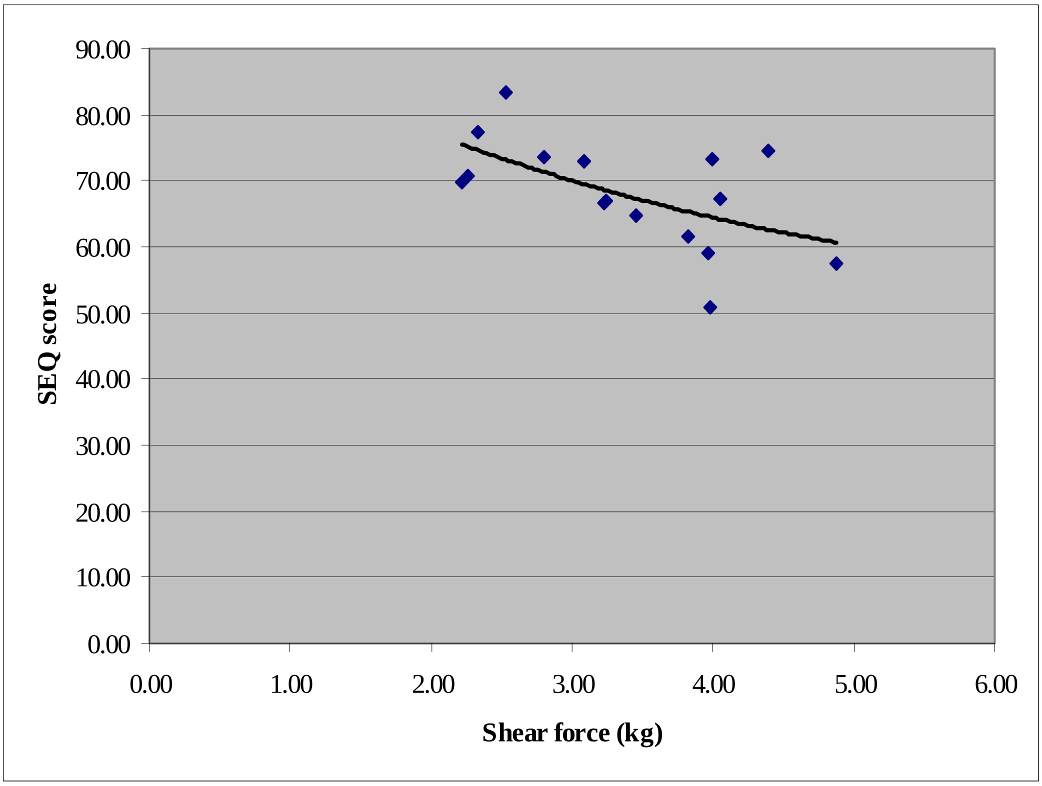

Figure 4: The relationship between shear force and SEQ score for grills.

With no design factors in the model, there was a curvilinear relationship between shear force and SEQ score (95.7 –10.7 sf + 0.7 sf²), with SEQ decreasing as shear force increased, but at a slower rate at higher levels of shear force. (R^2 = 33)

When shear force was related to roasts the relationship was not as apparent (Figure 5). This supports the previous conclusions that the methodology of the roast protocol needs to be critically reviewed.

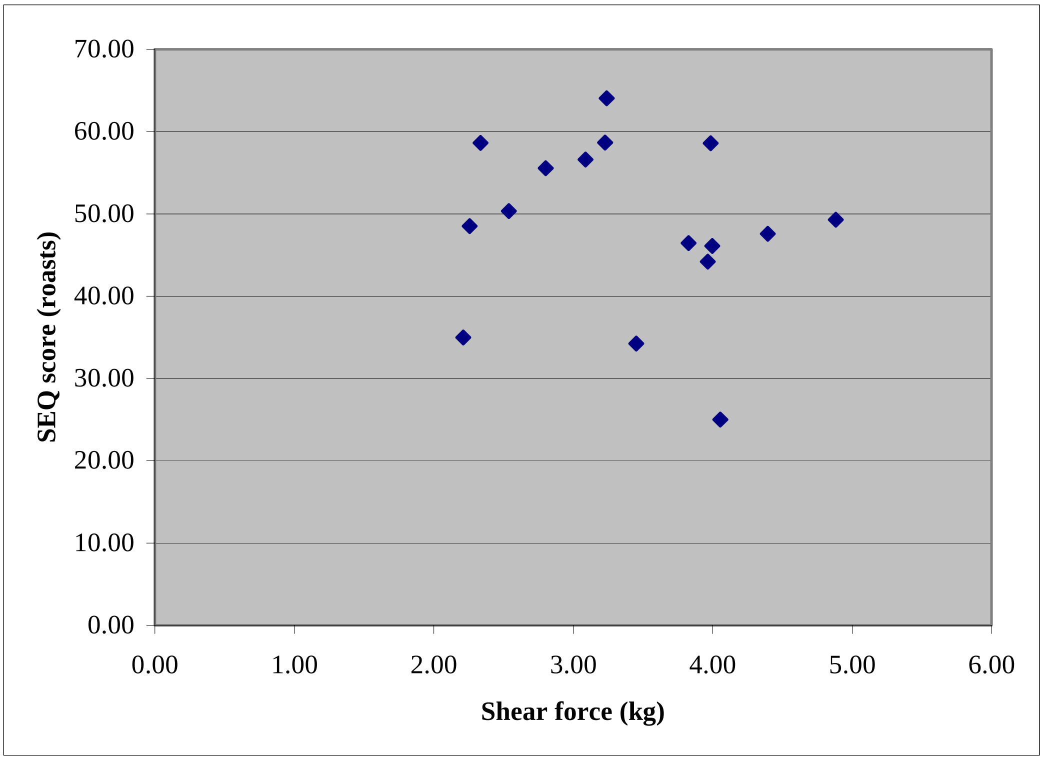

Figure 5: The relationship between shear force and SEQ score for roasts.

The limited results relating shear force to sensory suggest that there was not a particularly strong relationship between sensory and objective measurements. Therefore use of objective measurements as a replacement for sensory would not be warranted, although the small sample size of objective samples may have a place in specific experiments where a number of samples need to be processed from one muscle.

Conclusions

- Two muscles (LD and SM) had sensory and objective measurements taken, although data was limited in both cases.

- For grilled samples there was a relatively poor relationship between sensory and objective for the LD. For roasted samples the strength of the relationship between sensory and objective was much lower than for grilled samples.

APPENDIX I

Sub-class means (where n=4 or 5) for samples from 6 muscles which have been grilled and roasted, and were collected from ewes and lambs which were stimulated or not stimulated. (VL refers to m. vastus lateralis muscles which was grilled and TB refers to the M. triceps brachii which was roasted)

Muscle	Grill				Roast			
	Ewe		LMB		Ewe		LMB	
	NS	Stim	NS	Stim	NS	Stim	NS	Stim
Tend								
BF	36.3	33.6	46.7	69.4	50.8	33.7	55.6	56.7
GM	54.5	54.0	60.3	74.0	49.2	53.8	62.0	63.6
LD	55.0	61.2	74.2	80.8	46.9	55.1	67.0	73.5
SM	41.5	40.5	33.7	40.8	48.0	35.3	35.4	51.3
SV	52.1	60.4	71.4	75.0	55.3	54.0	52.7	55.0
VL/TB	55.0	51.4	62.7	69.1	63.9	56.9	56.4	63.5
Juicy								
BF	50.6	45.3	51.1	61.6	51.1	36.5	46.7	52.6
GM	51.4	50.8	54.9	62.0	49.3	53.2	54.0	51.3
LD	55.4	57.4	61.4	67.0	47.9	52.2	58.7	59.5
SM	49.0	44.0	39.2	38.6	59.4	44.4	38.3	51.8
SV	63.8	70.1	73.4	71.6	61.8	67.6	53.2	77.7
VL/TB	52.2	49.4	53.0	66.9	60.0	54.7	44.1	52.7
Fl Strength								
BF	55.1	55.2	56.6	58.1	57.3	46.5	49.6	55.6
GM	62.5	57.9	58.1	60.1	54.1	52.8	54.1	61.3
LD	58.9	65.7	59.7	62.2	57.1	53.3	60.8	59.7
SM	60.2	59.3	51.2	51.6	60.8	51.5	49.5	60.4
SV	59.3	59.4	64.6	58.1	57.3	60.1	51.9	55.4
VL/TB	57.0	55.3	58.6	60.4	57.8	55.9	47.8	54.6
Fl Like								
BF	55.3	46.5	57.6	66.4	51.1	42.0	48.7	53.0
GM	61.0	57.9	60.9	70.9	52.9	50.5	57.5	62.0
LD	65.8	63.9	69.7	72.1	52.7	57.1	62.8	66.6
SM	57.8	52.1	46.6	51.4	54.3	45.6	45.0	53.6
SV	56.3	65.3	69.4	70.7	52.3	54.2	50.7	56.8
VL/TB	58.0	52.5	62.3	67.8	60.1	55.6	49.8	63.0
Overall								
BF	49.2	38.4	52.4	66.2	51.5	36.2	49.9	54.7
GM	57.5	59.0	58.4	71.3	53.6	52.8	58.5	63.0
LD	61.3	65.1	73.1	76.1	52.5	56.3	62.6	68.0
SM	53.0	46.9	40.4	48.4	53.0	44.1	39.8	52.2
SV	54,3	62.2	71,1	70.8	53.8	54.4	49.7	57.5
VL/TB	55.2	52.8	62.4	69.6	63.8	56.4	51.6	64.6
SEQ								
BF	48.6	40.6	52.7	66.4	51.2	37.5	50.4	54.4
GM	57.3	56.8	59.2	70.8	52.1	52.3	58.5	61.7
LD	60.8	63.2	71.1	75.0	50.9	55.9	63.2	67.8
SM	51.7	46.9	40.8	46.8	53.0	42.8	40.3	52.4
SV	63.6	55.7	71.7	61.5	54.5	55.6	51.0	58.8
VL/TB	52.1	55.7	68.7	61.5	62.3	56.1	51.3	65.0