final report

Project Code: A.MFS.0196

Prepared by: Geoff Holds Stewart Eddie Paul Colby Andreas Kiermeier

South Australian Research and Development Institute

Date published: January 2010

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Extended shelf life evaluation of sliced lamb shoulders

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government and contributions from the Australian Meat Processor Corporation to support the research and development detailed in this publication.

Abstract

Several Australian sheep and lamb processors export vacuum packed lamb shoulders to Japan, where they are sliced, packed in overwrap trays and distributed to various supermarket outlets. In this trial lamb shoulders, typical of product destined for the Japanese market, were vacuum packed and stored for 78 days at 0°C. On five occasions during this period, lamb was sliced to a thickness of 4-5 mm, packed in overwrap trays and stored under retail conditions for zero and two days. Aerobic plate and lactic acid bacteria counts were obtained from vacuum packed product directly after opening and from sliced lamb. Sensory evaluations of sliced product were undertaken using an untrained Japanese sensory panel. The microbiological flora on the sliced product consisted predominantly of lactic acid bacteria. Stationary phase was reached after about 50 days of storage. Freshly sliced product had between 0.8 and 1.9 $\log_{10}$ cfu/g lower microbiological levels than stored sliced lamb. Sensory scores for appearance, colour, smell, taste, texture and overall impression were consistent across the 78 day storage period. Only retail storage of sliced lamb appeared to impact all sensory attributes - freshly cut product scored between ¼ and ½ of a score higher than stored retail product. However, no relationship between microbiology and sensory score was found and despite the high bacteria levels, product after 78 days was still in very good condition.

Executive Summary

Several Australian sheep and lamb processors export vacuum packed lamb shoulders to Japan. In Japan the lamb shoulders are centrally sliced (4-5 mm), packed in overwrap trays and distributed to various supermarket outlets, where they are put on display for sale.

Previous research indicates that consumer acceptability remains high for product that has been sliced and stored for up to four days, despite the fact that lactic acid producing bacteria were reaching approximately 7-8 log_{10} cfu per g.

The objective of this project was to assess the microbiological and organoleptic properties of vacuum packed lamb shoulders that had been stored for periods of up to 78 days. In addition, the relationships between microbiology and sensory attributes were of interest.

A total of 40 vacuum packed lamb shoulders were sourced and stored at -1 to 0°C for up to 78 days. A total of five sensory sessions were held at Days 22, 36, 50, 64, and 78 days post vacuum packing. For each session, four lamb shoulders were removed from cold storage two days prior to the sensory session and on the day of the sensory session. These shoulders were sliced (4-5 mm) and packed in overwrap trays. Packs sliced two days prior to sensory evaluation were stored in the cold store during the day and under lights in a commercial display cabinet at night.

Pieces of surface meat were collected from whole shoulders directly after opening the vacuum packs at each slicing occasion. Slices of retail product were collected immediately prior to sensory evaluation from product exposed to zero and two days retail storage. All microbiological samples were evaluated for Aerobic Plate Counts (APC) and Lactic Acid Bacteria (LAB). Levels of APC and LAB increased steadily up until 50 days of storage, by which time the stationary phase of 7-8 log_{10} cfu per g were reached. Levels of APC and LAB on sliced product reflected those of vacuum packed meat. Product freshly sliced exhibited an average of 0.8 to 1.9 log_{10} cfu/g less APC and LAB than product that had been stored for two days.

At each sensory session an untrained panel of Japanese consumers evaluated the product for appearance, colour, odour, taste, texture and overall impression. The organoleptic attributes were scored on a scale of 1 to 5 with 1 being the least desirable (Not good) and 5 being the most desirable (Good). No differences in sensory attributes were detected by the panel across the storage period – 22 day old product scored on average the same as 78 day old product. The only factor which had a significant effect on the sensory scores was the retail storage of sliced product, with stored product scoring lower on average – approximately ¼ score lower for Appearance and Colour and approximately ½ score lower for the remaining sensory attributes.

When sensory attributes were compared to microbiological levels no relationship could be found. That is, the Japanese consumer panel could not perceive difference in appearance, colour, odour, taste or texture in lamb with different levels of APC or LAB. However, consumers could perceive differences in freshly cut product and product that had been sliced and stored for two days, though the observed differences were not related to the age of the product and hence the levels of APC and LAB.

From the data collected in this study it is clear that there is no relationship between the sensory scores and the microbiological levels of sliced lamb shoulders. Consequently, there may be opportunities to work further with the Japanese importers and supermarket chains to modify existing shelf-life protocols without negatively affecting consumer acceptance.

Contents

1 Background

Several Australian sheep and lamb processors export vacuum packed lamb shoulders to Japan. In Japan the lamb shoulders are centrally sliced (4-5 mm), packed in overwrap trays and distributed to various supermarket outlets, where they are put on display for sale.

Previous research indicates that consumer acceptability remains high for product that has been sliced and stored for up to four days, despite the fact that lactic acid producing bacteria were reaching approximately 7-8 $\log_{10}$ cfu per g.

However, the effect of the length of storage time prior to unpacking and slicing on consumer acceptability has not been determined. As a result, a trial was undertaken to determine the effect of storage time on the shelf-life of whole vacuum-packed shoulders.

Over a period of up to 80 days, lamb shoulders were removed at regular intervals from commercial storage at 0°C. Shoulders were sliced, packed and stored for up to two days in a retail cabinet, before being assessed microbiologically and organoleptically by a Japanese consumer panel.

2 Project Objectives

To store vacuum packed lamb for up to 80 days and periodically assess the microbiological and organoleptic properties of the meat.

3 Methodology

3.1 Raw Materials

A Victorian meat processor vacuum packed lamb shoulders (n = 40), two per pack, on 30 August 2009. The shoulders were stored under refrigerated conditions (in 10 cartons) at the processor and sent to Adelaide via refrigerated transport. They were stored in a cold store in Adelaide until pickup and unrefrigerated transport to Regency International TAFE[1].

3.2 Slicing and Packaging

Slicing and packaging of product into retail packs was undertaken at about 10:00 on two occasions - two days prior to and on the day of the sensory evaluation (see Table 1). All processing was undertaken in a room chilled to 8°C. On each occasion, two packs of shoulders were opened aseptically. After opening, small surface pieces, totalling 25 g were removed for microbiological testing (see Section 3.5). A qualified butcher trimmed each shoulder and sliced it by hand to a thickness of 4-5 mm. End slices were discarded. Clean knives and boards were used for each shoulder and hands were washed between shoulders.

Slices were packed into white polystyrene trays and covered with plastic wrap[2] to a pack weight of approximately 200-250 g. Packs were identified by a coloured dot – the same colour was used for packs of meat that originated from the shoulders that had been vacuum packed together. No vacuum packaging, MAP or heat sealing were used.

[1] Transport distance was 8 km and duration was 20 minutes.
[2] As used in Japan – a roll of cling film was provided by MLA.

Table 1: Activity schedule

Activity	Day	Product Age (days)
Shoulder collection	Wednesday, 30 September 2009	0
Slicing only	Tuesday, 20 October 2009	20
Slicing and Sensory trial	Thursday, 22 October 2009	22
Slicing only	Tuesday, 3 November 2009	34
Slicing and Sensory trial	Thursday, 5 November 2009	36
Slicing only	Tuesday, 17 November 2009	48
Slicing and Sensory trial	Thursday, 19 November 2009	50
Slicing only	Tuesday, 1 December 2009	62
Slicing and Sensory trial	Thursday, 3 December 2009	64
Slicing only	Tuesday, 15 December 2009	76
Slicing and Sensory trial	Thursday, 17 December 2009	78

3.3 Storage

Retail packs that were produced on Tuesdays were held in the main cold store. At approximately 16:00 on Tuesdays and Wednesdays, packs were removed from the cold store, placed in the retail display cabinet (2°C) and stored overnight under lights. Packs were removed at approximately 09:30 the following morning and transferred back to the main cold store. On Thursdays, the packs were removed from the retail cabinet and placed in a domestic refrigerator (5°C) in the kitchen adjoining the sensory laboratory until sensory evaluation.

Retail packs that were produced on Thursdays were held in the main cold store until approximately 14:00, when they were collected and stored in the domestic refrigerator in the kitchen adjoining the sensory laboratory until sensory evaluation.

Product was removed from the refrigerator 30 minutes before testing and placed on the kitchen bench.

3.4 Temperature Monitoring

Temperature loggers set to record temperatures hourly were placed in three of the ten cartons when the whole shoulders were packed in Victoria. These were removed after arrival at the Regency International TAFE campus at 12:43 on 6 October 2009 and sent back to the processor.

Five new temperature loggers were set to record the temperature every three hours and stored with the lamb shoulders throughout the trial. At each “Slicing only” occasion (Table 1) one data logger was removed from the stored, whole shoulders and placed in a tray pack (under the meat) for monitoring of the retail storage conditions.

At the time of the sensory evaluation the data logger was removed from the tray and placed with the samples collected for microbiological testing.

3.5 Microbiological Testing

Two 25 g samples, each comprising surface pieces of 3-5 g, were collected from each lamb shoulder after the vacuum packs were opened and immediately prior to slicing (referred to as **“pieces”**).

Slices were collected from all tray packs immediately prior to the cooking part of each sensory evaluation and divided into triplicate samples of 25 g each (referred to as **“slices”**). Slices were stored in a domestic refrigerator (4-5°C) until the following day, when they were tested.

All meat samples were homogenised for 60 s in 225 ml Peptone Saline Solution using a stomacher and serial dilutions prepared using 9 mL volumes of Peptone Saline Solution.

3.5.1 Aerobic Plate Count

Serial decimal dilutions were inoculated (1 mL) onto Petrifilm Aerobic Count Plates (3M Corp) and incubated at 25°C ± 1°C for 96 h ± 3 h. After incubation, plates were examined as per the manufacturer's instructions and the aerobic plate count calculated. The limit of detection was 10 cfu/g.

3.5.2 Lactic Acid Bacteria

Volumes of each decimal dilution (2 mL) were added to an equal volume of double-strength MRS broth (Amyl Media Pty Ltd, Dandenong, Australia) and mixed thoroughly. An aliquot (1 mL) of the MRS suspension was inoculated onto Petrifilm Aerobic Count Plates (3M Corp) and incubated at 25°C ± 1°C for 96 h ± 3 h. Films were incubated in sealed pouches containing an anaerobic atmosphere generated by a GENbag anaer kit, (BioMerieux sa, Marcy l'Etoile, France). After incubation the plates were examined as per the manufacturer's instructions and the count calculated. The limit of detection was 20 cfu/g.

3.6 Sensory Evaluation

Sensory testing was undertaken between 18:00 and 19:30 on 22 October (Session 1), 5 November (Session 2), 19 November (Session 3), 3 December (Session 4) and 17 December 2009 (Session 5) in the sensory laboratories at the Regency International TAFE campus.

3.6.1 Sensory Panel

The panel consisted of 16 untrained Japanese consumers from the Adelaide region. The panel was sourced through the Australia-Japan Friendship society and TAFE SA contacts. Panellists were paid AU$70 per sensory session. The criteria placed on the panel were as follows:

- Lived in Australia for less than two years
- Eaten lamb previously

The panel profile is provided in Appendix 1: Sensory Panel Profile. Unfortunately, it was not possible to establish a balance with respect to male and female panellists – only two male Japanese consumers could be found for this trial. The panel was not trained prior to evaluating the product. However, the procedures for the sensory evaluations, including the scoring, were explained to the panel in English and Japanese.

Not all panellists were able to attend each session, therefore, 10 panellists at most were utilised at each session, depending on their availability (Table 2).

Table 2: Summary of the number of sessions attended by each panellist

Panellist	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16
Sessions attended	5	5	5	2	4	3	3	5	4	4	2	1	2	2	1

3.6.2 Sensory Score Sheet

The Sensory Score Sheet utilised was the same as that used by a retail company in Japan (supplied by MLA) and was presented in Japanese and English. It contained the following six questions (Appendix 3: Sensory Scoring Sheet):

1. What do you think about the appearance?
2. What do you think about the colour?
3. What do you think about the smell?
4. What do you think about the taste?
5. What do you think about the texture?
6. What do you think about the product overall?

Each of these questions were rated as either Good, Slightly Good, Don't know, Not very good, Not good. In addition, an area for additional comments was provided.

3.6.3 Sensory Testing

At each sensory session panellists were presented with a total of four packs, identified only by a colour dot. Two replicate packs (gold and white) had been sliced two days prior to evaluation and two other replicate packs (silver and orange) had been sliced on the day. The order in which different coloured packs were presented to panellists was randomised for each sensory session (Table 3).

Table 3: Tasting order for each sensory session

Taste Order	Session 1	Session 2	Session 3	Session 4	Session 5
First	Gold	White	Gold	Orange	Silver
Second	Silver	Orange	White	Gold	Orange
Third	Orange	Silver	Silver	White	White
Fourth	White	Gold	Orange	Silver	Gold

Ten panellists were seated in individual booths. Five packs of the product were presented to the panellists – one pack for every two panellists – to answer Questions 1 and 2. The product was opened via a cut on one side of the packaging and presented to the first panellist. After evaluation the packaging was cut on the opposite side to the first cut and presented to the second panellist.

A fully qualified chef, who trained at Tokyo Shokuryo Gakuin, cooked the product for approximately 45 seconds on each side using a stainless steel pan. Pans were washed and dried between product ages. The product was served on individual plates and presented to each panellist to answer Questions 4-6. No condiments were served.

Sugarless, mild, green tea (Oolong variety) was made available to panellists, for palate cleansing after each cooked product tasting.

All sensory evaluations were completed for one pack before moving onto the next product.

3.7 Data Sets and Statistical Analysis

Two data sets were generated as part of this project – microbiological and sensory data. For the microbiological data the following variables were defined and used in the analyses – they are given here for ease of reference.

- **Age**: The age in days of the lamb shoulders, from packing at the processing plant to microbiological analysis of the meat. Assumes that packing took place at 09:00.
- **Sample Type**: The type of meat samples – "pieces" or "slices".
- **Storage**: Indicates whether a "slices" sample had been stored for two days (stored) or sliced that day (fresh cut) before sensory analysis and collection for microbiological analysis. Not applicable for "pieces" samples.
- **Sample**: The coloured dot to indicate, for sensory purposes, whether the sample had been fresh cut (orange and silver) or stored for two days (white and gold).
- **APC**: The result of the Aerobic Plate Count.
- **LAB**: The result of the Lactic Acid Bacteria count.

Due to technical problems, three LAB results could not be obtained.

Similarly, the variables defined for the sensory data are as follows.

- **Age**: The age of the meat (in days) at the day of sensory testing.
- **Session**: An integer between 1 and 5 indicating the sensory session.
- **Order**: The order in which product was tasted on any one day – given by values 1 to 4.
- **Cut on**: The day on which the meat was cut.
- **Storage**: Indicates whether the sample had been stored for two days (stored) or sliced that day (fresh cut) before sensory analysis and collection for microbiological analysis.
- **Sample**: The colour of the dot used to identify products.
- **Tester**: The ID (1 to 16) of the panellist who made the assessment.
- **Appearance**: The score relating to the panellist's assessment of the general appearance of the raw product – where: 5 = Good, 4 = Slightly Good, 3 = Don't know, 2 = Not very good, 1 = Not good.
- **Colour**: The score relating to the panellist's assessment of the colour of the raw product – a value between 1 and 5 (see Appearance score).
- **Smell**: The score relating to the panellist's assessment of the smell of the raw product – a value between 1 and 5 (see Appearance score).
- **Taste**: The score relating to the panellist's assessment of the taste of the cooked product – a value between 1 and 5 (see Appearance score).
- **Texture**: The score relating to the panellist's assessment of the texture of the cooked product – a value between 1 and 5 (see Appearance score).
- **Overall**: The score relating to the panellist's overall assessment of the product – a value between 1 and 5 (see Appearance score).

3.7.1 Model Fitting

The temperature profile graph was prepared in Microsoft Excel 2003. All other graphics and statistical models were produced using the R software version 2.10.1 (R Development Core Team 2009).

Straight line regression models were fitted to the microbiological results of **pieces** to estimate the growth rate during the storage time up to and including 50 days, by which time the stationary phase had been reached.[3] These models were of the form (R notation)

log10(APC) ~ age and **log10(LAB) ~ age**

where **age** was considered as a continuous variable. The significance of the linear term was assessed using a t-test and a significance level of 0.05.

The effect of storage on the microbiological levels of slices was assessed using a linear model (two-way ANOVA). Both **storage** and **session**, and their interaction, were included in the model as factors, which allowed the storage effect to be different for each session – this appeared important in relation to the modelling the effects during the stationary phase. The models were of the following form (R notation)

log10(APC) ~ storage + session + storage:session

The significance of the predictors was assessed with an ANOVA table using Type II Sums of Squares and a significance level of 0.05. Non-significant predictors were removed from the model using a stepwise approach, observing marginality, until all predictors in the model remained significant.

Significant effects in sensory characteristics were obtained by fitting linear models (multiple regression). The models fitted utilised tasting order as linear effects,[4] while panellist (taster), product age (age)[5] and storage duration (storage) were used as factors, with no specific implied ordering. The storage effect was allowed to differ with product age as well as with the order of testing. The full model for Appearance was of the following form (R notation) and models for the other sensory attributes were similar:

appearance ~ tester + age + storage + order + storage:age + storage:order

The significance of the predictors was assessed with an ANOVA table using Type II Sums of Squares and a significance level of 0.05. Non-significant predictors were removed from the model using a stepwise approach, observing marginality, until all predictors in the model remained significant.

All models were checked for appropriateness of the fit using standard diagnostics plots, including the fitted values plot, Normal quantile-quantile plot, scale-location plot and the leverage plot.

The microbiological results were compared against the seven different sensory scores by taking the mean of the replicate microbiological results of slices for each session and storage type (each colour separately) and plotting them against the corresponding mean sensory score.

The relationships between the mean $\log_{10}$ APC and mean $\log_{10}$ LAB and the mean sensory scores were assessed using linear regression models. In these models the mean $\log_{10}$ APC and mean $\log_{10}$ LAB were used as continuous variables and storage was used as a factor – a different regression line was allowed for each storage condition (fresh cut and stored). The

[3] As determined by visual inspection of the corresponding scatter plot. It should be noted that the linear regression line was fitted only to the linear growth component of the data and no full growth curve, with stationary components, were fitted to the data.

[4] This was done to assess a general trend (increase/decrease) in the order, that is, does the last product tested generally rate better or worse than the first product tested.

[5] Product age was included as a factor rather than a linear effect due to the microbiological profiles observed. In addition, using age as a factor provides a more broadly applicable test (of which a linear increase/decrease is a more specific alternative).

statistical significance of the predictor variables was assessed using an ANOVA table using Type II Sums of Squares and a significance level of 0.05.

4 Results

Temperature log results are presented in Section 4.1 and microbiological test results are presented in Section 4.2. Results from the sensory evaluations are presented in Sections 4.3-4.5, based on the following three questions:

1. Would a consumer buy it (colour, appearance)?
2. Would a consumer cook it (no 'bad' odour on opening)?
3. What is the taste experience?

Comparisons between microbiological and sensory results are given in Section 4.7.

All the statistical models fitted and their results can be found in Appendix 5: Statistical Analyses.

4.1 Temperature Results

The temperatures at which the product was stored for the period of the trial are displayed in Figure 1. From this plot it can be seen that the storage temperatures of whole, vacuum-packed shoulders were appropriate, that is, generally between -2 and 0°C.

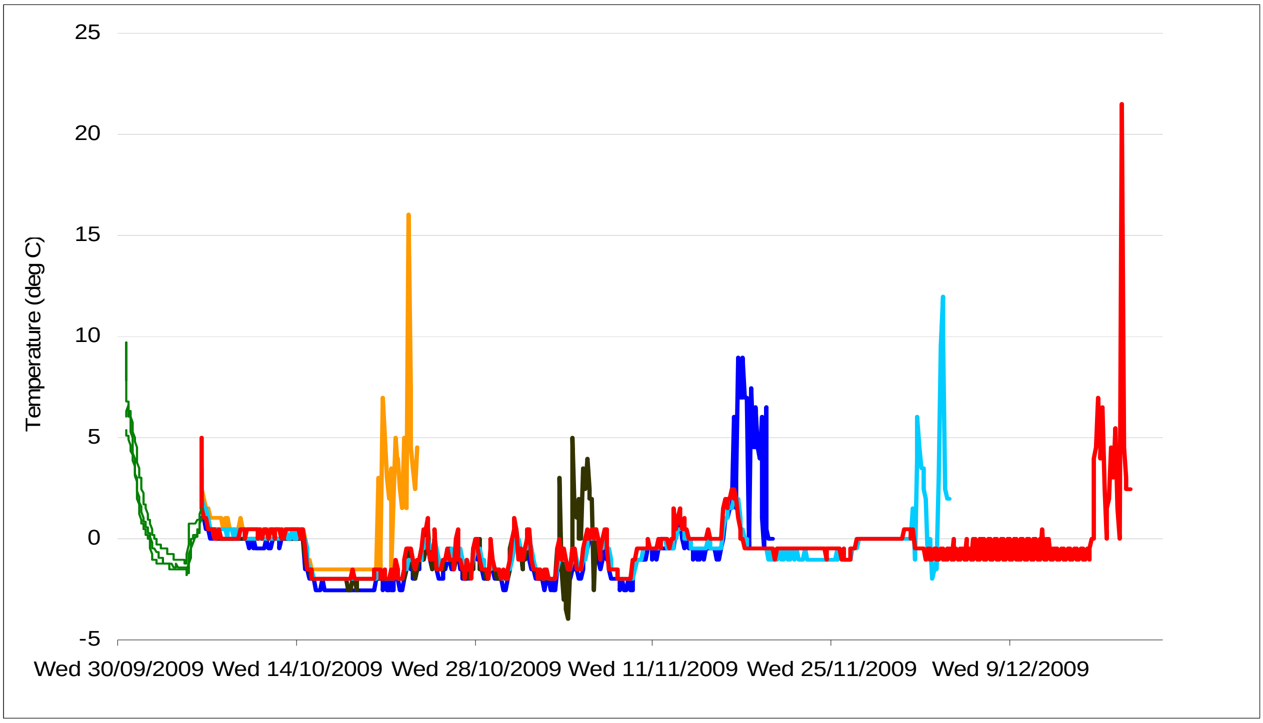

Figure 1 Temperature profiles – different colours represent different temperature loggers, except for the three loggers which were placed with the product by the processor (all in green).

The increases in temperatures which occur every two weeks coincide with slicing and retail storage of product.

Some of the temperatures logs (yellow, teal, red) also show large temperature spikes. These coincide with the sensory sessions when product was removed from the refrigerator approximately 30 minutes prior to sensory evaluation.

It should also be noted that maximum outside temperatures in Adelaide between 8 and 15 November were all in excess of 37°C. This resulted in the retail cabinet temperatures reaching up to 9°C.

A more detailed temperatures profile covering the “retail phase” of the product sliced for the first sensory session is shown in Figure 2. This was fairly typical of the other sessions. The following events occurred during this period:

- Product was sliced and packed at about 10:00 on Tuesday 20 Oct 2009 and then stored in the cool room.
- The packed product was moved to the retail cabinet at about 16:00 and stored under lights.
- At about 09:30 on Wednesday 21 Oct 2009 the product was moved to the cool room.
- The packed product was moved to the retail cabinet at about 16:00 and stored under lights.
- At about 09:30 on Thursday 22 Oct 2009 the product was moved to the domestic refrigerator in the kitchen adjoining the sensory labs.
- Product was removed from the refrigerator at about 17:30 and held on the kitchen bench until sample collection and sensory evaluation.

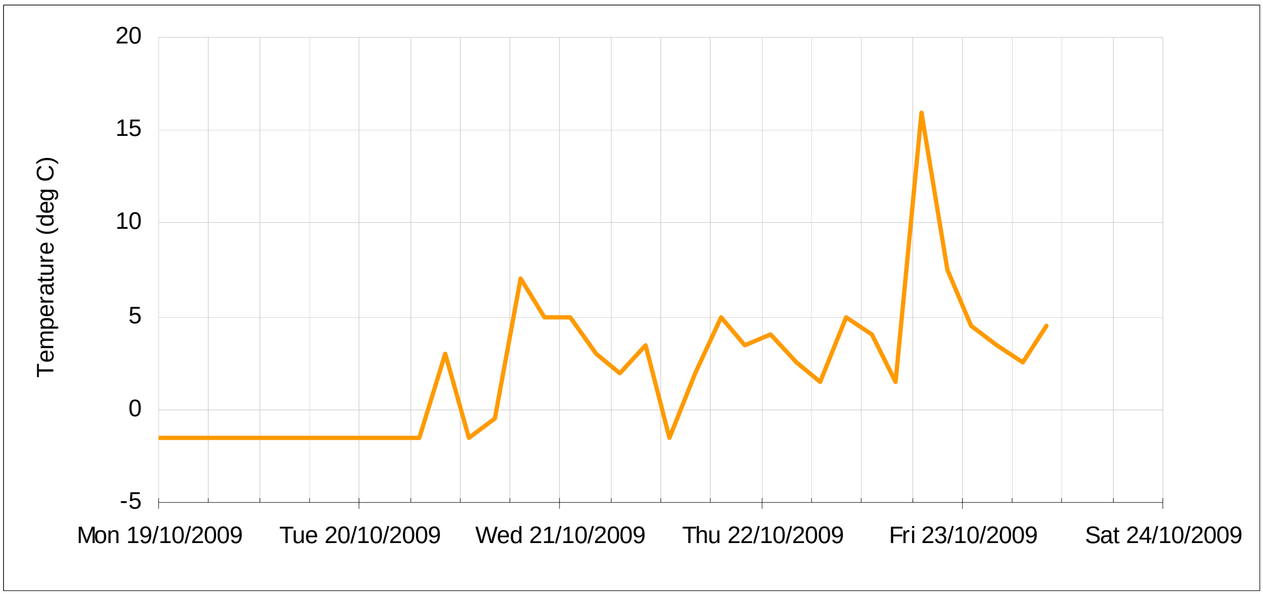

Figure 2 Temperature profile for the “retail period” of product prepared for the first sensory session.

4.2 Microbiological Results

4.2.1 Aerobic Plate Count of Pieces

A plot of the log_{10} APC of pieces over time is presented in **Figure 3**. From this plot the following observations can be made.

- Stationary phase of APC is reached by 50 days.
- The APCs of approximately 5-5.5 log_{10} cfu/g around the 35 days compare well with counts of about 5.5 log_{10} cfu/g obtained in a previous study for similar age product (MLA project A.MFS.0185).
- Assuming a linear growth phase (on the log_{10} scale) between age 20 and 50 days, the rate of growth is estimated to be 0.15 log_{10} cfu/g per day or 1.05 log_{10} cfu/g per week.

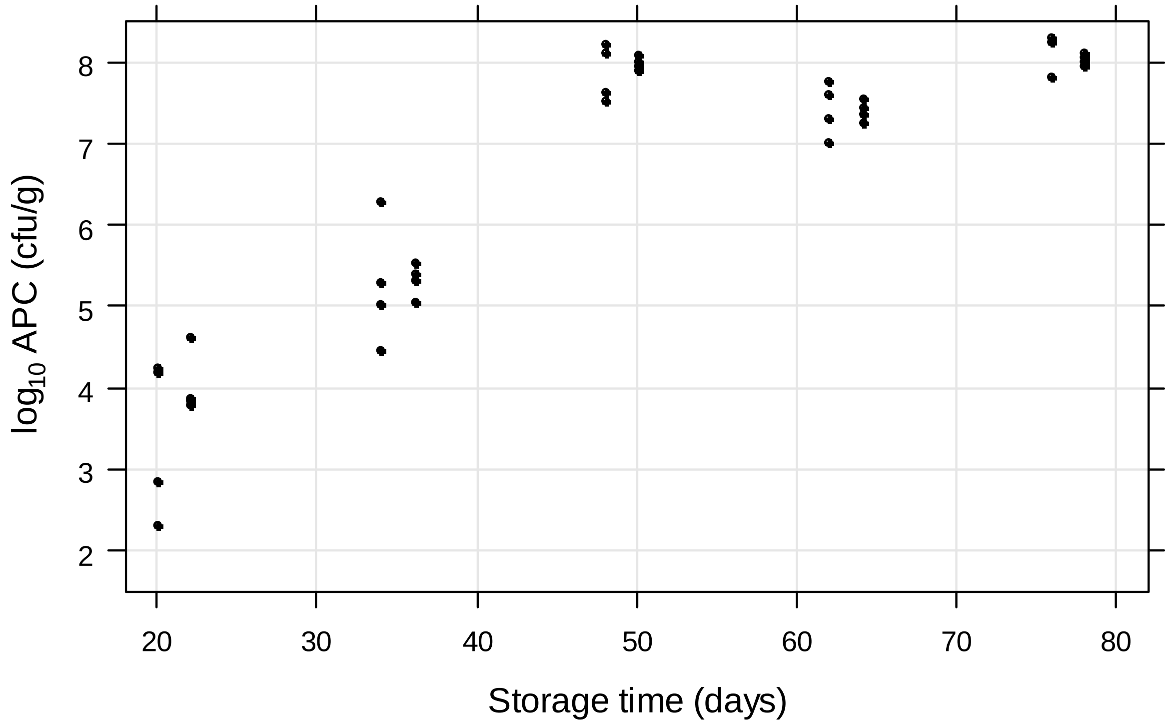

Figure 3: Aerobic Plate Counts for surface pieces collected directly after opening vacuum packed lamb shoulders.

4.2.2 Aerobic Plate Count of Slices

A plot of the log_{10} APC of slices over time is presented in Figure 4. From this plot the following observations can be made.

- Stationary phase of APC is reached by 50 days, which agrees with the observations made on surface pieces.
- The effect of sliced meat storage (“stored” versus “fresh cut”) was different for each session (P-value = 0.006). The APC for stored slices were between 0.78 and 1.91 log_{10} cfu/g higher than for freshly cut slices.
- Stored samples were 48 hours older than freshly cut slices and the average log_{10} APC was 1.28 log_{10} cfu/g higher than fresh cut slices. These results agree reasonably well with the rate of increase of 0.42 log_{10} cfu/g per day estimated in a previous project (MLA project A.MFS.0185).

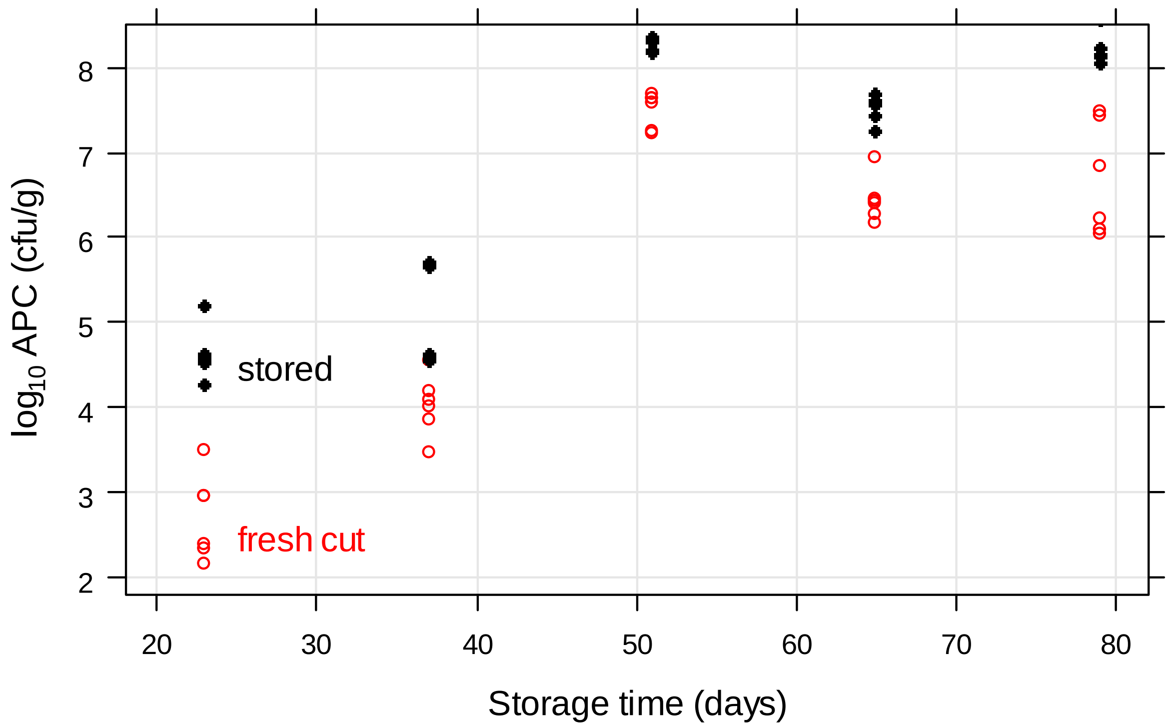

Figure 4: Aerobic Plate Counts for slices of lamb shoulder which had been cut two days prior to (“stored”) or on the day (“fresh cut”) of sensory evaluation.

4.2.3 Lactic Acid Bacteria of Pieces

A plot of the log_{10} LAB over time is presented in Figure 5. From this plot the following observations can be made.

- Stationary phase of LAB is reached by 50 days, which agrees with the observation made for APC.
- The LABs of approximately 5 log_{10} cfu/g at 35 days agree well with counts of about 5.5 log_{10} cfu/g obtained in a previous study for similar age product (MLA project A.MFS.0185).
- Assuming a linear growth phase (on the log_{10} scale) between age 20 and 50 days, the rate of growth is estimated to be 0.16 log_{10} cfu/g per day or 1.10 log_{10} cfu/g per week.

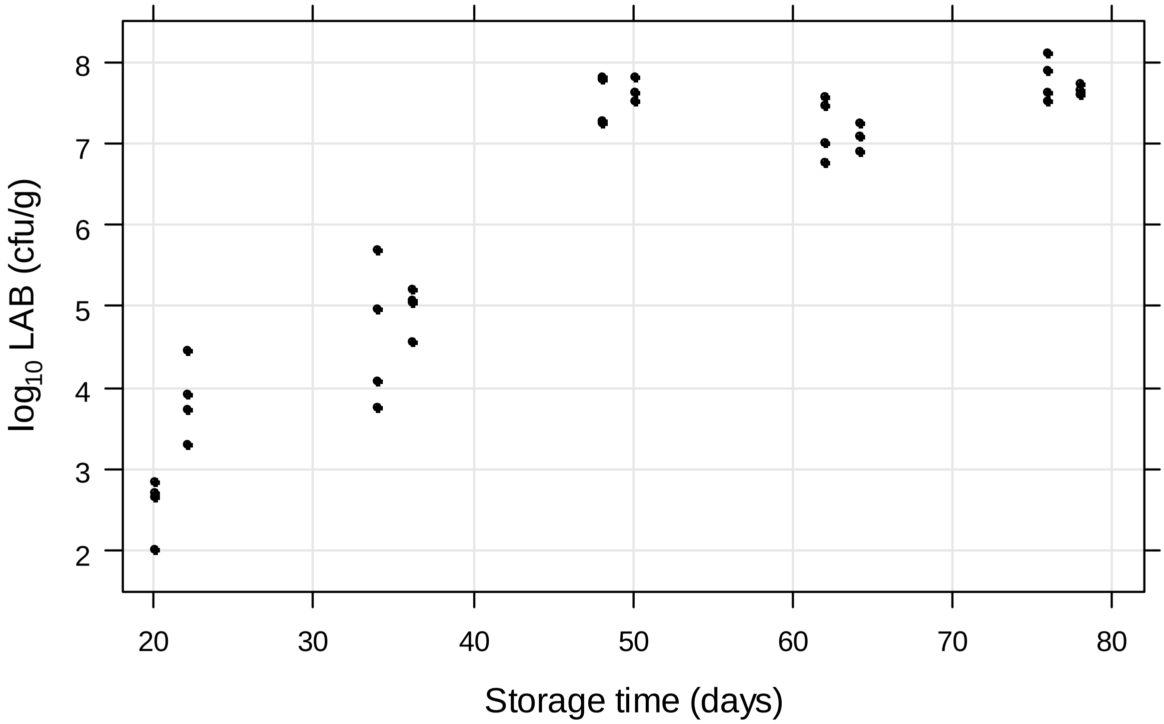

Figure 5: Lactic Acid Bacteria Counts for surface pieces collected directly after opening vacuum packed lamb shoulders.

4.2.4 Lactic Acid Bacteria of Slices

A plot of the $\log_{10}$ LAB of slices over time is presented in Figure 6. From this plot the following observations can be made.

- Stationary phase of LAB is reached by 50 days, which is in line with the observations made on surface pieces.
- The effect of sliced meat storage ("stored" versus "fresh cut") was the same for each session (P-value = 0.105). The LAB for stored slices were between an average 1.08 $\log_{10}$ cfu/g higher than for freshly cut slices.
- These results compare reasonably well with the rate of increase of 0.45 $\log_{10}$ cfu/g per day estimated in a previous project (MLA project A.MFS.0185)

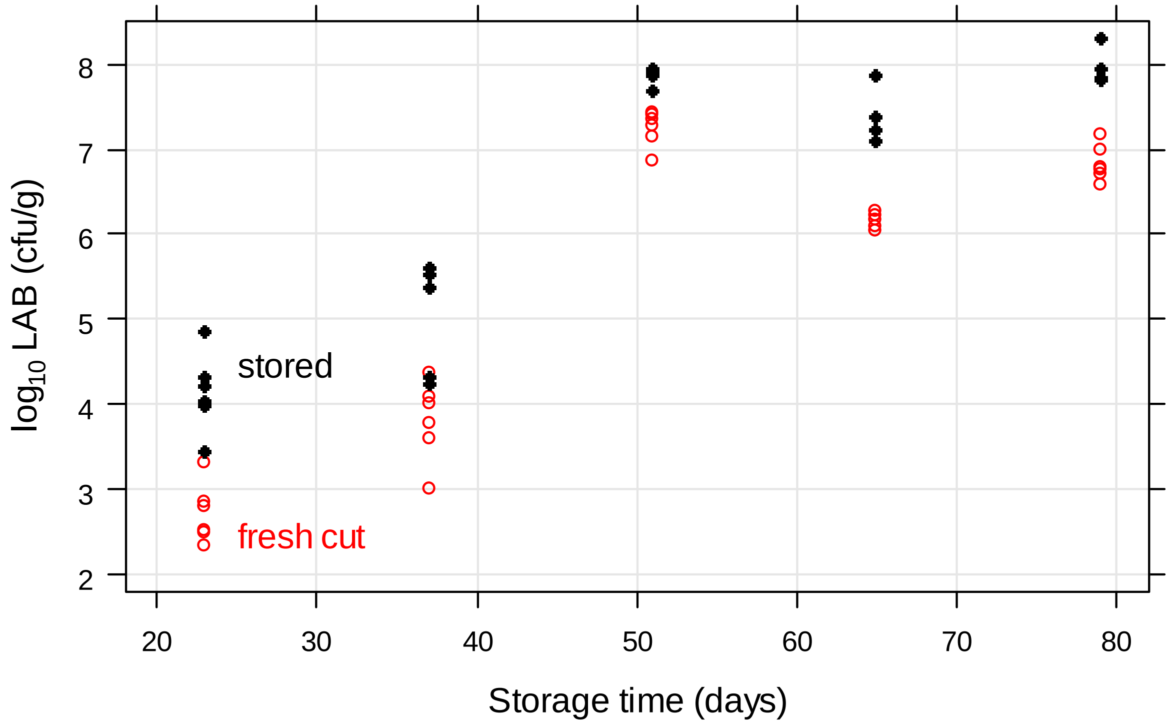

Figure 6: Lactic Acid Bacteria Counts for slices of lamb shoulder which had been cut two days prior to ("stored") or on the day ("fresh cut") of sensory evaluation.

4.3 Would a consumer buy it?

The appearance and colour of the product were judged by the sensory panel by looking at the raw lamb slices presented in overwrapped white polystyrene trays, similar to the way a consumer would look at the product when trying to make a buying decision in the supermarket.

4.3.1 Appearance

Bar charts of the actual scores for each sensory session (columns) and sliced meat storage duration (fresh cut = silver and orange; stored = gold and white) are presented in Figure 7. From the model fitted to the data the following conclusions can be drawn – these are provided in the order in which terms were removed from the model.

- There was no significant interaction between the order of testing and the storage of sliced product (P-value = 0.72).
- There was no significant interaction between storage and product age (P-value = 0.22).
- There were no significant differences in the mean appearance scores between the different product ages (P-value = 0.66).
- There were no significant differences between the mean appearance scores between product tasted first and product tasted last (P-value = 0.16), that is, there was no testing order effect.
- There were significant differences between panellists (P-value < 0.001).
- Stored product scored significantly lower than freshly cut product by an average of 0.24 untis (P-value = 0.03) across all product ages.
- The predicted Appearance score for freshly cut product is 4.4 and for stored product is 4.1.

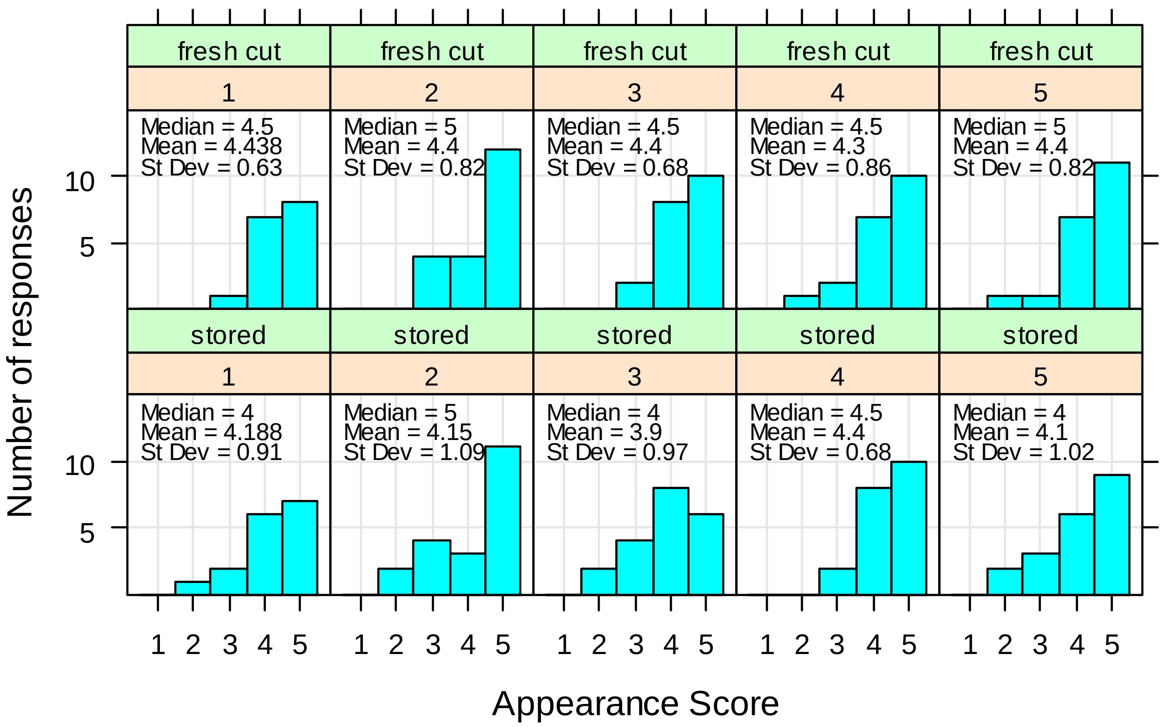

Figure 7: Bar charts of the Appearance Scores for each sensory session (columns – 1 to 5) and storage duration (stored = gold and white; fresh cut = silver and orange).

4.3.2 Colour

Bar charts of the actual scores for each sensory session (columns) and sliced meat storage duration (fresh cut = silver and orange; stored = gold and white) are presented in Figure 8. From the model fitted to the data the following conclusions can be drawn – these are provided in the order in which terms were removed from the model.

- There was no significant interaction between the order of testing and the storage of sliced product (P-value = 0.71).
- There was no significant interaction between storage and product age (P-value = 0.27).

- There were no significant differences in the mean colour scores between the different product ages (P-value = 0.58).
- There were no significant differences between the mean colour scores between product tasted first and product tasted last (P-value = 0.09), that is, there was no testing order effect.
- There were significant differences between panellists (P-value < 0.001).
- Stored product scored significantly lower than freshly cut product by an average of 0.23 units (P-value = 0.03) across all product ages.
- The predicted Colour score for freshly cut product is 4.5 and for stored product is 4.3.

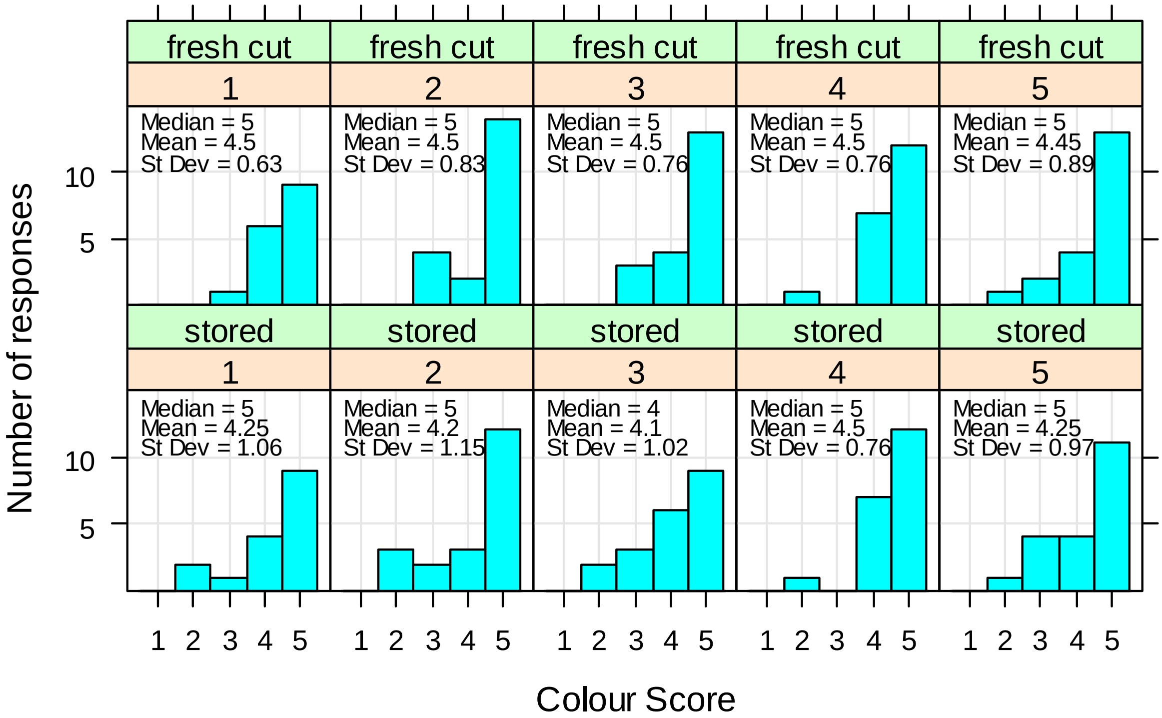

Figure 8: Bar charts of the Colour Scores for each sensory session (columns – 1 to 5) and storage duration (stored = gold and white; fresh cut = silver and orange).

4.4 Would a consumer cook it?

The odour of the product was judged by the sensory panel by smelling the product after an incision had been made into the plastic wrap. This is as close as possible to a consumer opening the pack at home just prior to cooking.

Bar charts of the actual scores for each sensory session (columns) and sliced meat storage duration (fresh cut = silver and orange; stored = gold and white) are presented in **Figure 9**. From the model fitted to the data the following conclusions can be drawn – these are provided in the order in which terms were removed from the model.

- There was no significant interaction between storage and product age (P-value = 0.32).
- There were no significant differences in the mean scores between the different product ages (P-value = 0.52).

- There was no significant interaction between the order of testing and the storage of sliced product (P-value = 0.28).
- There were no significant differences between the mean scores between product tasted first and product tasted last (P-value = 0.15), that is, there was no testing order effect.
- There were significant differences between panellists (P-value < 0.001).
- Stored product scored significantly lower than freshly cut product by an average of 0.43 units (P-value = 0.001) across all product ages.
- The predicted Smell score for freshly cut product is 4.3 and for stored product is 3.8.

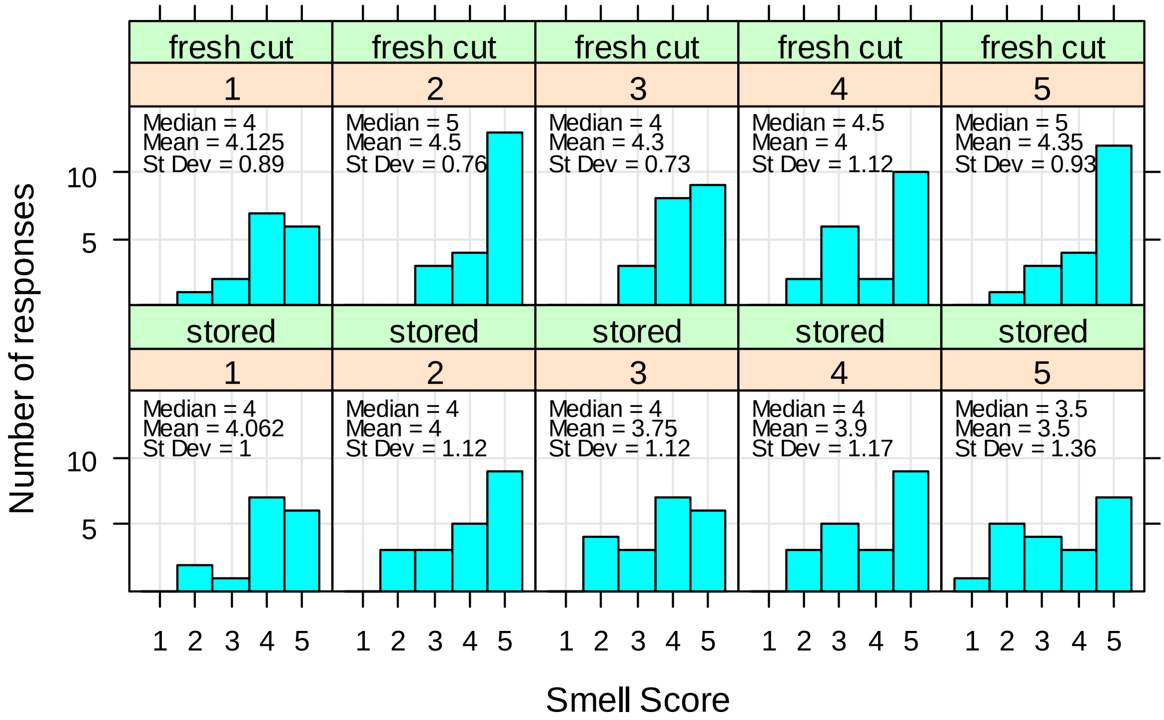

Figure 9: Bar charts of the Smell Scores for each sensory session (columns – 1 to 5) and storage duration (stored = gold and white; fresh cut = silver and orange).

4.5 What is the taste experience?

The taste and texture of the product were judged by the sensory panel by eating small pieces of lamb slices which had been briefly (45 s) cooked on both sides. This was similar to the way a consumer would experience the product at home.

4.5.1 Taste

Bar charts of the actual scores for each sensory session (columns) and sliced meat storage duration (fresh cut = silver and orange; stored = gold and white) are presented in Figure 10. From the model fitted to the data the following conclusions can be drawn – these are provided in the order in which terms were removed from the model.

- There was no significant interaction between storage and product age (P-value = 0.60).

- There was no significant interaction between the order of testing and the storage of sliced product (P-value = 0.35).
- There were no significant differences between the mean taste scores between product tasted first and product tasted last (P-value = 0.78), that is, there was no testing order effect.
- There were no significant differences in the mean taste scores between the different product ages (P-value = 0.19).
- There were significant differences between panellists (P-value < 0.001).
- Stored product scored significantly lower than freshly cut product by an average of 0.5 units (P-value < 0.001).
- The predicted Taste score for freshly cut product is 4.3 and for stored product is 3.8.

Figure 10: Bar charts of the Taste Scores for each sensory session (columns – 1 to 5) and storage duration (stored = gold and white; fresh cut = silver and orange).

4.5.2 Texture

Bar charts of the actual scores for each sensory session (columns) and sliced meat storage duration (fresh cut = silver and orange; stored = gold and white) are presented in Figure 11. From the model fitted to the data the following conclusions can be drawn – these are provided in the order in which terms were removed from the model.

- There was no significant interaction between the order of testing and the storage of sliced product (P-value = 0.68).
- There were no significant differences between the mean texture scores between product tasted first and product tasted last (P-value = 0.90), that is, there was no testing order effect.
- There was no significant interaction between storage and product age (P-value = 0.14).

- There were no significant differences in the mean texture scores between the different product ages (P-value = 0.37).
- There were significant differences between panellists (P-value < 0.001).
- Stored product scored significantly lower than freshly cut product by an average of 0.43 units (P-value = 0.002) across all product ages.
- The predicted Texture score for freshly cut product is 4.3 and for stored product is 3.9.

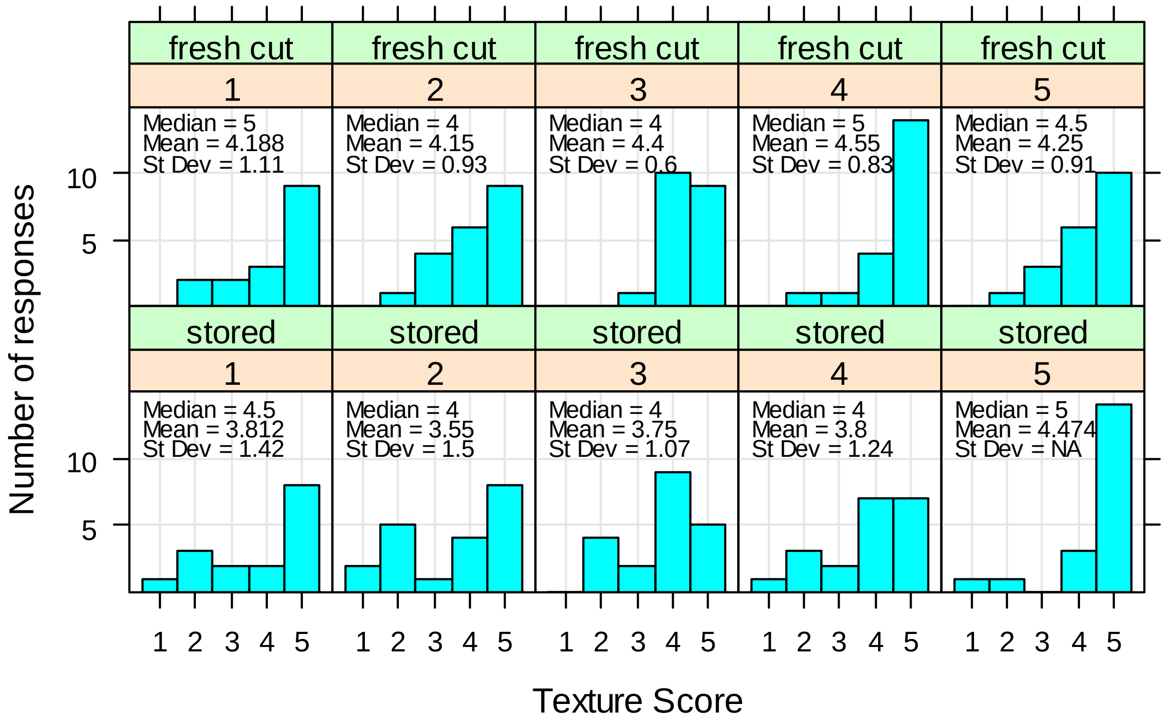

Figure 11: Bar charts of the Texture Scores for each sensory session (columns – 1 to 5) and storage duration (stored = gold and white; fresh cut = silver and orange).

4.6 Overall Assessment

Bar charts of the actual scores for each sensory session (columns) and sliced meat storage duration (fresh cut = silver and orange; stored = gold and white) are presented in Figure 12. From the model fitted to the data the following conclusions can be drawn – these are provided in the order in which terms were removed from the model.

- There was no significant interaction between storage and product age (P-value = 0.77).
- There were no significant differences in the mean overall scores between the different product ages (P-value = 0.29).
- There was no significant interaction between the order of testing and the storage of sliced product (P-value = 0.22).
- There were no significant differences between the mean texture scores between product tasted first and product tasted last (P-value = 0.59), that is, there was no testing order effect.

- There were significant differences between panellists (P-value < 0.001).
- Stored product scored significantly lower than freshly cut product by an average of 0.51 (P-value < 0.001) across all product ages.
- The predicted Overall score for freshly cut product is 4.3 and for stored product is 3.8.

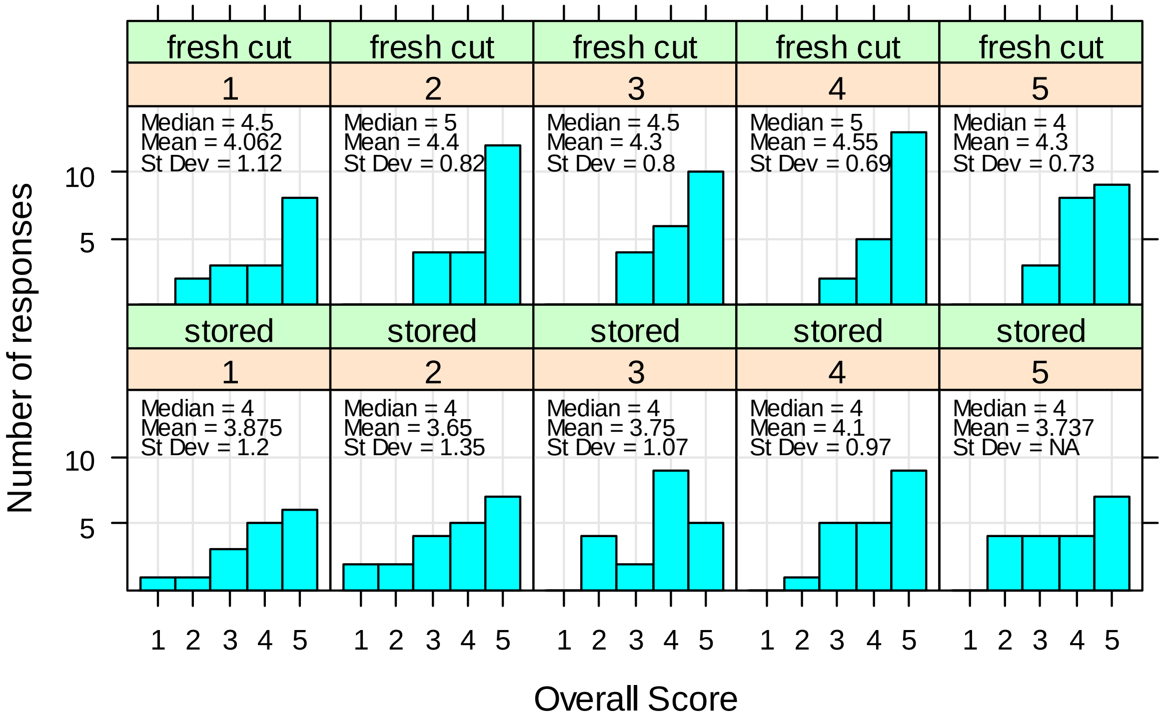

Figure 12: Bar charts of the Overall Scores for each sensory session (columns – 1 to 5) and storage duration (stored = gold and white; fresh cut = silver and orange).

4.7 Comparing Microbiological and Sensory results

As indicated in the Methodology section, the comparison of microbiological results of slices and sensory results was undertaken by calculating the mean for both results for each session and storage type (fresh cut and stored) and comparing them graphically and using linear regression models.

The scatter plots of the mean sensory scores versus the mean $\log_{10}$ APC are shown in

Figure 13 and those of mean sensory scores versus the mean $\log_{10}$ LAB in Figure 14. From these plots it can be seen that there is little to no relationship between the microbiological levels and any of the sensory scores. However, for some sensory attributes the stored product appears to score lower than freshly cut product.

These observations are confirmed by the results of fitting linear regression models (for results see Appendix 5). For the APC models, storage was significant for all sensory attributes except Appearance, which agrees with the findings in the previous sections.[6] APC was only marginally

[6] Note that storage was marginally significant (P-value – 0.03) in the analysis of the Appearance scores. The lack of detecting this is likely due to the use of mean scores and mean $\log_{10}$ APC and LAB.

significant (P-value = 0.049) for texture – texture score increased by 0.078 units for every 1 $\log_{10}$ increase in mean APC.

For the LAB models, storage was significant for all sensory attributes except Appearance, which agrees with the findings in the previous sections. LAB was not a significant predictor of sensory score for any of the sensory attributes.

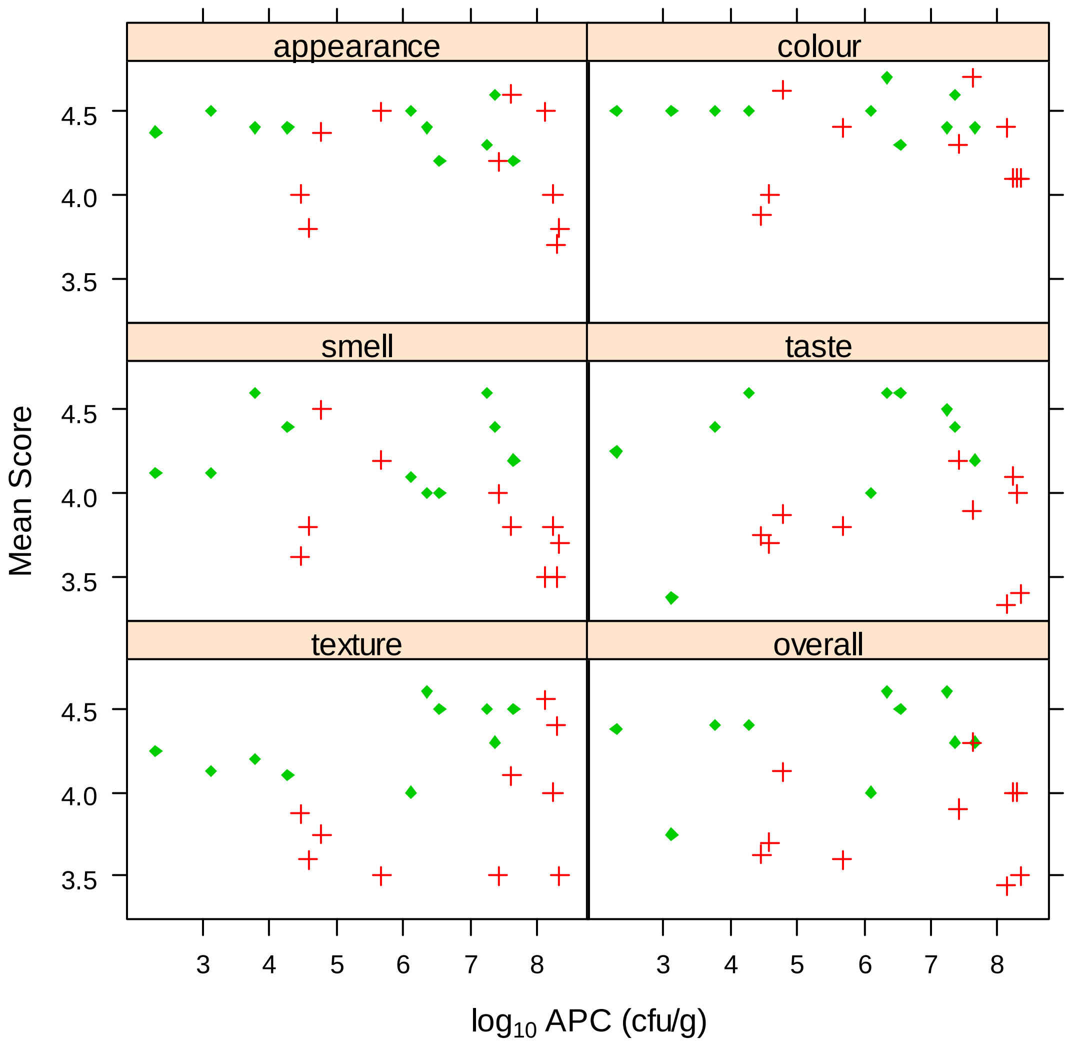

Figure 13: Scatter plot of the mean sensory score versus the $\log_{10}$ APC (cfu/g) for each sensory attribute – red crosses indicate stored product (gold and white) and green dots indicate fresh cut product (silver and orange).

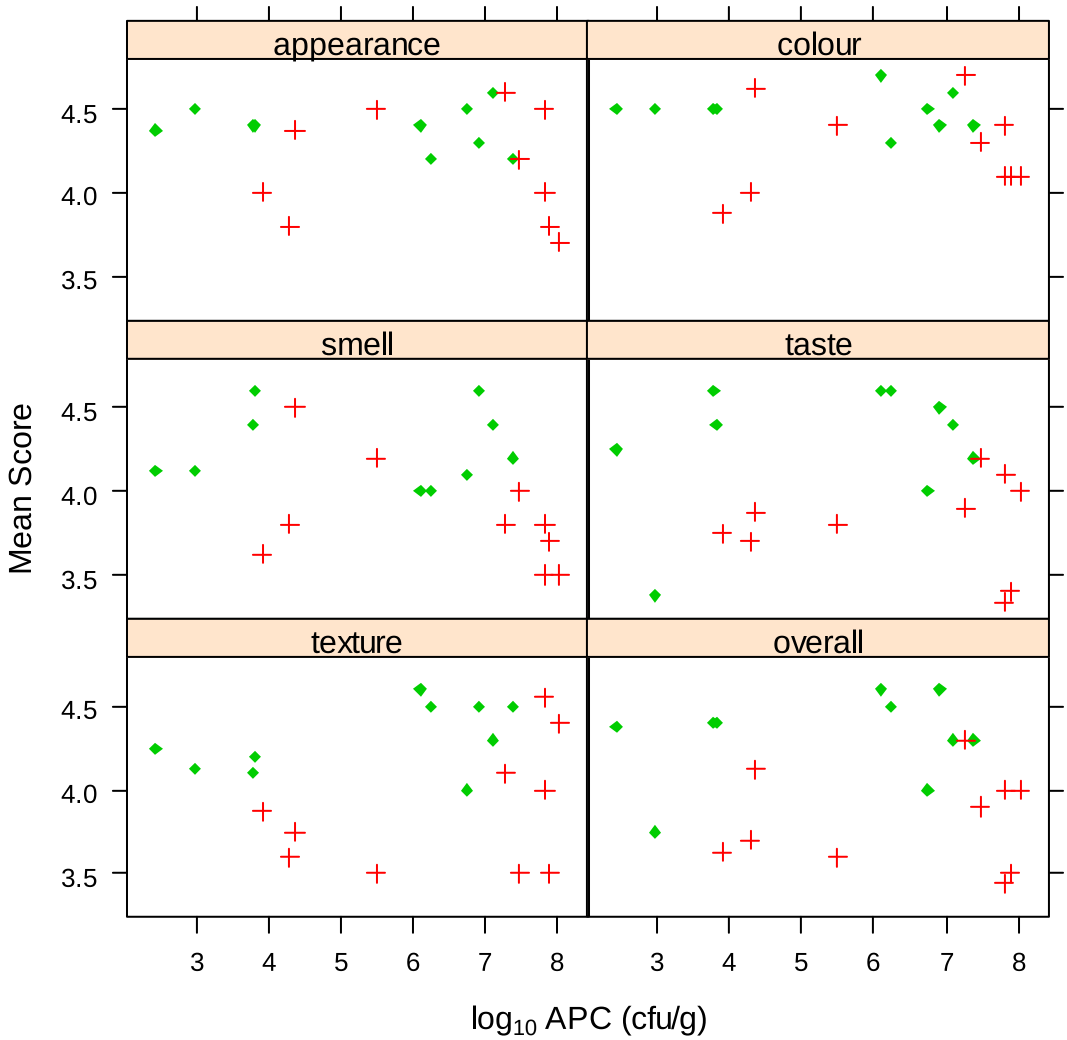

Figure 14: Scatter plot of the mean sensory score versus the log_{10} LAB (cfu/g) for each sensory attribute – red crosses indicate stored product (gold and white) and green dots indicate fresh cut product (silver and orange).

5 Discussion

The product sourced for this trial was typical of product currently exported to Japan and all processing steps – storage, slicing, packing, and retail storage – were aimed to mimic commercial practices as closely as possible. The principal aim of this study was to store whole vacuum packed lamb shoulders for up to 80 days under commercial storage conditions and regularly evaluate the sensory characteristics of the product after slicing.

As expected, levels of APC and LAB of surface pieces cut from lamb shoulders increased steadily at a rate of about 0.15 log_{10} cfu/g per day until the stationary phase of 7-8 log_{10} cfu/g was reached after 50 days of storage.

Throughout the trial, shoulders were sliced and stored for up to two days in a retail cabinet before being subjected to microbiological and sensory testing. The levels of APC and LAB of sliced product reflected those of surface pieces at each testing occasion. On average, product that had been stored for two days had an average of 1.28 and 1.08 $\log_{10}$ cfu/g more APC and LAB, respectively, than freshly cut product. These results agree reasonably well with results obtained from a previous study (MLA project A.MFS.085).

The sensory evaluations were undertaken with the help of an untrained Japanese consumer panel. While the panel was untrained, their thoroughness was highly commendable. Despite the extended storage and the high microbiological levels, sensory results were only affected by whether product had been stored or had been freshly cut on the day of the evaluation. On average, stored product scored between 0.25 and 0.5 units lower than freshly cut product. Nevertheless, average scores for stored product were around 3.8-3.9, indicating that members of the sensory panel were willing to buy, cook and consume the product throughout the trial.

While the sensory panel consisted of Japanese consumers who had eaten lamb in the past, they were untrained. This meant that panellists may have interpreted the scores for the sensory characteristics differently. For example, in Session 2 Panellist 6 scored the appearance of the white pack as a 2, with the comment "The colour was not very fresh", while Panellist 3 scored the identical pack as a 5. Consequently, the absolute scores of the sensory attributes are likely to be different compared to those that would be obtained using a well trained panel. A well trained panel would result in less variable scores.

Nevertheless, from the data collected in this study it is clear that there is no relationship between the sensory scores and the microbiological levels of sliced lamb shoulders. Consequently, there may be opportunities to work further with the Japanese importers and supermarket chains to modify existing shelf-life setting protocols without negatively affecting consumer acceptance.

6 Success in Achieving Objectives

To store vacuum packed lamb for up to 80 days and periodically assess the microbiological and organoleptic properties.

The objectives of this work have been achieved as follows:

- Vacuum packed lamb shoulders were stored under refrigerated conditions for up to 78 days.
- The vacuum packed product was assessed microbiologically throughout this storage period.
- At fortnightly intervals, lamb shoulders were removed from storage, sliced and stored for up to two days before being presented to an untrained sensory panel of Japanese consumers for sensory evaluation.

7 Acknowledgements

We would like to thank the participants in the Japanese sensory panel for their diligent work and the Regency TAFE SA staff, Steve Maslin (butcher) and Tod Dolphin (chef) for their assistance in preparing and cooking the meat. We also acknowledge Dr John Sumner for organising the vacuum packed lamb shoulders and their delivery to SARDI.

8 Bibliography

R Development Core Team (2009) R: A language and environment for statistical computing. (R Foundation for Statistical Computing: Vienna, Austria).

9 Appendices

9.1 Appendix 1: Sensory Panel Profile

Panellist	Gender	Age	Region	Lived in Australia	Eaten Lamb	Last Time eaten Lamb	Eaten Lamb Where?
1	M	40	Chugoku	>5years	>10times	within last month	At home AU
2	F	20	Kanto	<6months	3-5times	>2years ago	Restaurant in Japan
3	F	30	Kanto	6-12months	>10times	within last 6 months	All 4 options
4	F	20	Chuba	6-12months	3-5times	within last month	At home AU
5	F	30	Chuba	>5 years	>10times	within last month	At home AU
6	F	30	Tohoku	1-2year	1-2times	>2years ago	?
7	F	40	Kanto	1-2years	>10times	within last year	Restaurant in NZ
8	F	30	Tohoku/ Kanto	1-2year	>10 times	within last month	At home AU
10	M	40	Kanto	<6months	>10times	within last month	At Restaurant in AU
11	F	20	Kanto	1-2year	>10times	within last 6 months	At home AU
12	F	40	Kanto	1-2years	>10times	within last month	At home AU
13	F	20	Kanto	2-5years	3-5times	within last 6 months	At Restaurant in AU
14	F	40	Chuba	2-5years	>10times	This week	At home AU
15	F	30	Kanto	2-5years	5-10times	within last month	At Restaurant in AU
16	F	30	Kyushu	2-5years	3-5times	within last year	At Restaurant in AU

9.2 Appendix 3: Sensory Scoring Sheet

Japanese Version

1． 外観についてはどう感じますか

よい　　ややよい　　どちらちともいえない　　ややよくない　　よくない

2． 色についてはどうですか

よい　　ややよい　　どちらちともいえない　　ややよくない　　よくない

3． 香りについてはどうですか

よい　　ややよい　　どちらちともいえない　　ややよくない　　よくない

4． 味についてはどうですか

よい　　ややよい　　どちらちともいえない　　ややよくない　　よくない

5． 食感についてはどうですか

よい　　ややよい　　どちらちともいえない　　ややよくない　　よくない

6． 全体としてはどうですか

よい　　ややよい　　どちらちともいえない　　ややよくない　　よくない

コメント：

English Version

Consumer Sensory Score Sheet (English)

Sample number:

1. What do you think about the appearance?

Good	Slightly Good	Don't know	Not very good	Not good

2. What do you think about the colour?

Good	Slightly Good	Don't know	Not very good	Not good

3. What do you think about the smell?

Good	Slightly Good	Don't know	Not very good	Not good

4. What do you think about the taste?

Good	Slightly Good	Don't know	Not very good	Not good

5. What do you think about the texture?

Good	Slightly Good	Don't know	Not very good	Not good

6. What do you think about the product overall?

Good	Slightly Good	Don't know	Not very good	Not good

Comments:

This space is for consumers to write comments if they wish.

9.3 Appendix 3: Microbiological Data

lab.id	collect	sample.type	storage	session	sample	test	age	apc	lab
FS09-1728	20/10/2009 08:30	pieces			white	20/10/2009 11:00	20.08	700	700
FS09-1729	20/10/2009 08:30	pieces			white	20/10/2009 11:00	20.08	15000	100
FS09-1730	20/10/2009 08:30	pieces			gold	20/10/2009 11:00	20.08	200	440
FS09-1731	20/10/2009 08:30	pieces			gold	20/10/2009 11:00	20.08	17000	520
FS09-1738	22/10/2009 11:30	pieces			silver	22/10/2009 13:00	22.17	41000	28000
FS09-1739	22/10/2009 11:30	pieces			silver	22/10/2009 13:00	22.17	6900	8000
FS09-1740	22/10/2009 11:30	pieces			orange	22/10/2009 13:00	22.17	7100	2000
FS09-1741	22/10/2009 11:30	pieces			orange	22/10/2009 13:00	22.17	5900	5200
FS09-1742	22/10/2009 19:00	slices	stored	1	white	23/10/2009 09:00	23.00	36000	2800
FS09-1743	22/10/2009 19:00	slices	stored	1	white	23/10/2009 09:00	23.00	18000	9400
FS09-1744	22/10/2009 19:00	slices	stored	1	white	23/10/2009 09:00	23.00	37000	21000
FS09-1745	22/10/2009 19:00	slices	stored	1	gold	23/10/2009 09:00	23.00	150000	72000
FS09-1746	22/10/2009 19:00	slices	stored	1	gold	23/10/2009 09:00	23.00	41000	16000
FS09-1747	22/10/2009 19:00	slices	stored	1	gold	23/10/2009 09:00	23.00	34000	11000
FS09-1748	22/10/2009 19:00	slices	fresh cut	1	silver	23/10/2009 09:00	23.00	870	700
FS09-1749	22/10/2009 19:00	slices	fresh cut	1	silver	23/10/2009 09:00	23.00	870	640
FS09-1750	22/10/2009 19:00	slices	fresh cut	1	silver	23/10/2009 09:00	23.00	3100	2000
FS09-1751	22/10/2009 19:00	slices	fresh cut	1	orange	23/10/2009 09:00	23.00	250	300
FS09-1752	22/10/2009 19:00	slices	fresh cut	1	orange	23/10/2009 09:00	23.00	220	320
FS09-1753	22/10/2009 19:00	slices	fresh cut	1	orange	23/10/2009 09:00	23.00	140	220
FS09-1761	3/11/2009 08:30	pieces			gold	3/11/2009 10:30	34.06	100000	5500
FS09-1762	3/11/2009 08:30	pieces			gold	3/11/2009 10:30	34.06	28000	12000
FS09-1763	3/11/2009 08:30	pieces			white	3/11/2009 10:30	34.06	1900000	480000
FS09-1764	3/11/2009 08:30	pieces			white	3/11/2009 10:30	34.06	190000	91000
FS09-1765	5/11/2009 11:30	pieces			silver	5/11/2009 14:00	36.21	330000	160000
FS09-1766	5/11/2009 11:30	pieces			silver	5/11/2009 14:00	36.21	240000	120000
FS09-1767	5/11/2009 11:30	pieces			orange	5/11/2009 14:00	36.21	110000	36000
FS09-1768	5/11/2009 11:30	pieces			orange	5/11/2009 14:00	36.21	200000	110000
FS09-1769	5/11/2009 19:00	slices	stored	2	gold	6/11/2009 09:00	37.00	43000	21000
FS09-1770	5/11/2009 19:00	slices	stored	2	gold	6/11/2009 09:00	37.00	37000	17000
FS09-1771	5/11/2009 19:00	slices	stored	2	gold	6/11/2009 09:00	37.00	36000	21000
FS09-1772	5/11/2009 19:00	slices	stored	2	white	6/11/2009 09:00	37.00	510000	390000
FS09-1773	5/11/2009 19:00	slices	stored	2	white	6/11/2009 09:00	37.00	460000	340000

lab.id	collect	sample.type	storage	session	sample	test	age	apc	lab
FS09-1774	5/11/2009 19:00	slices	stored	2	white	6/11/2009 09:00	37.00	440000	230000
FS09-1775	5/11/2009 19:00	slices	fresh cut	2	silver	6/11/2009 09:00	37.00	3000	4000
FS09-1776	5/11/2009 19:00	slices	fresh cut	2	silver	6/11/2009 09:00	37.00	10000	12000
FS09-1777	5/11/2009 19:00	slices	fresh cut	2	silver	6/11/2009 09:00	37.00	7000	6000
FS09-1778	5/11/2009 19:00	slices	fresh cut	2	orange	6/11/2009 09:00	37.00	36000	23000
FS09-1779	5/11/2009 19:00	slices	fresh cut	2	orange	6/11/2009 09:00	37.00	12000	1000
FS09-1780	5/11/2009 19:00	slices	fresh cut	2	orange	6/11/2009 09:00	37.00	15000	10000
FS09-1807	17/11/2009 08:00	pieces			gold	17/11/2009 12:00	48.13	33000000	17000000
FS09-1808	17/11/2009 08:00	pieces			gold	17/11/2009 12:00	48.13	42000000	19000000
FS09-1809	17/11/2009 08:00	pieces			white	17/11/2009 12:00	48.13	130000000	59000000
FS09-1810	17/11/2009 08:00	pieces			white	17/11/2009 12:00	48.13	160000000	65000000
FS09-1857	19/11/2009 11:00	pieces			silver	19/11/2009 12:00	50.13	87000000	42000000
FS09-1858	19/11/2009 11:00	pieces			silver	19/11/2009 12:00	50.13	79000000	41000000
FS09-1859	19/11/2009 11:00	pieces			orange	19/11/2009 12:00	50.13	99000000	32000000
FS09-1860	19/11/2009 11:00	pieces			orange	19/11/2009 12:00	50.13	120000000	64000000
FS09-1861	19/11/2009 19:00	slices	stored	3	gold	20/11/2009 09:00	51.00	160000000	71000000
FS09-1862	19/11/2009 19:00	slices	stored	3	gold	20/11/2009 09:00	51.00	150000000	47000000
FS09-1863	19/11/2009 19:00	slices	stored	3	gold	20/11/2009 09:00	51.00	210000000	88000000
FS09-1864	19/11/2009 19:00	slices	stored	3	white	20/11/2009 09:00	51.00	220000000	76000000
FS09-1865	19/11/2009 19:00	slices	stored	3	white	20/11/2009 09:00	51.00	200000000	75000000
FS09-1866	19/11/2009 19:00	slices	stored	3	white	20/11/2009 09:00	51.00	230000000	80000000
FS09-1867	19/11/2009 19:00	slices	fresh cut	3	silver	20/11/2009 09:00	51.00	17000000	7300000
FS09-1868	19/11/2009 19:00	slices	fresh cut	3	silver	20/11/2009 09:00	51.00	39000000	19000000
FS09-1869	19/11/2009 19:00	slices	fresh cut	3	silver	20/11/2009 09:00	51.00	18000000	14000000
FS09-1870	19/11/2009 19:00	slices	fresh cut	3	orange	20/11/2009 09:00	51.00	42000000	22000000
FS09-1871	19/11/2009 19:00	slices	fresh cut	3	orange	20/11/2009 09:00	51.00	43000000	26000000
FS09-1872	19/11/2009 19:00	slices	fresh cut	3	orange	20/11/2009 09:00	51.00	49000000	25000000
FS09-1942	1/12/2009 08:30	pieces			gold	1/12/2009 10:30	62.06	40000000	28000000
FS09-1943	1/12/2009 08:30	pieces			gold	1/12/2009 10:30	62.06	20000000	10000000
FS09-1944	1/12/2009 08:30	pieces			white	1/12/2009 10:30	62.06	10000000	5900000
FS09-1945	1/12/2009 08:30	pieces			white	1/12/2009 10:30	62.06	58000000	36000000
FS09-1978	3/12/2009 11:00	pieces			silver	3/12/2009 14:30	64.23	23000000	12000000
FS09-1979	3/12/2009 11:00	pieces			silver	3/12/2009 14:30	64.23	27000000	12000000
FS09-1980	3/12/2009 11:00	pieces			orange	3/12/2009 14:30	64.23	35000000	18000000
FS09-1981	3/12/2009 11:00	pieces			orange	3/12/2009 14:30	64.23	18000000	7600000

lab.id	collect	sample.type	storage	session	sample	test	age	apc	lab
FS09-1982	3/12/2009 19:00	slices	stored	4	white	4/12/2009 09:00	65.00	36000000	72000000
FS09-1983	3/12/2009 19:00	slices	stored	4	white	4/12/2009 09:00	65.00	18000000	12000000
FS09-1984	3/12/2009 19:00	slices	stored	4	white	4/12/2009 09:00	65.00	27000000	
FS09-1985	3/12/2009 19:00	slices	fresh cut	4	silver	4/12/2009 09:00	65.00	2500000	1600000
FS09-1986	3/12/2009 19:00	slices	fresh cut	4	silver	4/12/2009 09:00	65.00	1900000	
FS09-1987	3/12/2009 19:00	slices	fresh cut	4	silver	4/12/2009 09:00	65.00	8800000	1900000
FS09-1988	3/12/2009 19:00	slices	stored	4	gold	4/12/2009 09:00	65.00	48000000	17000000
FS09-1989	3/12/2009 19:00	slices	stored	4	gold	4/12/2009 09:00	65.00	36000000	17000000
FS09-1990	3/12/2009 19:00	slices	stored	4	gold	4/12/2009 09:00	65.00	41000000	23000000
FS09-1991	3/12/2009 19:00	slices	fresh cut	4	orange	4/12/2009 09:00	65.00	2600000	1200000
FS09-1992	3/12/2009 19:00	slices	fresh cut	4	orange	4/12/2009 09:00	65.00	1500000	1100000
FS09-1993	3/12/2009 19:00	slices	fresh cut	4	orange	4/12/2009 09:00	65.00	2800000	1500000
FS09-2098	15/12/2009 08:30	pieces			gold	15/12/2009 10:00	76.04	63000000	33000000
FS09-2099	15/12/2009 08:30	pieces			gold	15/12/2009 10:00	76.04	63000000	41000000
FS09-2100	15/12/2009 08:30	pieces			white	15/12/2009 10:00	76.04	170000000	79000000
FS09-2101	15/12/2009 08:30	pieces			white	15/12/2009 10:00	76.04	190000000	130000000
FS09-2215	17/12/2009 09:30	pieces			silver	17/12/2009 10:45	78.07	110000000	44000000
FS09-2216	17/12/2009 09:30	pieces			silver	17/12/2009 10:45	78.07	130000000	54000000
FS09-2217	17/12/2009 09:30	pieces			orange	17/12/2009 10:45	78.07	100000000	38000000
FS09-2218	17/12/2009 09:30	pieces			orange	17/12/2009 10:45	78.07	86000000	43000000
FS09-2219	17/12/2009 19:00	slices	stored	5	gold	18/12/2009 11:00	79.08	110000000	65000000
FS09-2220	17/12/2009 19:00	slices	stored	5	gold	18/12/2009 11:00	79.08	170000000	
FS09-2221	17/12/2009 19:00	slices	stored	5	gold	18/12/2009 11:00	79.08	130000000	65000000
FS09-2222	17/12/2009 19:00	slices	stored	5	white	18/12/2009 11:00	79.08	370000000	200000000
FS09-2223	17/12/2009 19:00	slices	stored	5	white	18/12/2009 11:00	79.08	140000000	68000000
FS09-2224	17/12/2009 19:00	slices	stored	5	white	18/12/2009 11:00	79.08	140000000	88000000
FS09-2225	17/12/2009 19:00	slices	fresh cut	5	silver	18/12/2009 11:00	79.08	1100000	5100000
FS09-2226	17/12/2009 19:00	slices	fresh cut	5	silver	18/12/2009 11:00	79.08	1200000	5800000
FS09-2227	17/12/2009 19:00	slices	fresh cut	5	silver	18/12/2009 11:00	79.08	1600000	5900000
FS09-2228	17/12/2009 19:00	slices	fresh cut	5	orange	18/12/2009 11:00	79.08	30000000	15000000
FS09-2229	17/12/2009 19:00	slices	fresh cut	5	orange	18/12/2009 11:00	79.08	6900000	3700000
FS09-2230	17/12/2009 19:00	slices	fresh cut	5	orange	18/12/2009 11:00	79.08	26000000	9800000

9.4 Appendix 4: Sensory Data

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
22	1	1	20	stored	1	gold	5	4	4	4	3	4	Overall looks/tastes the freshest, meat was bit tough
22	1	1	20	stored	2	gold	5	5	5	5	5	5	Appearance looks beautiful, then colour was nice and shiny. Couldn't smell bad meat so smells ok. Easy to eat, tender and overall very good
22	1	1	20	stored	3	gold	4	5	4	4	4	4	Looks beautiful, but the size of pieces is not uniform. Could smell typical lamb. Tender and nice but texture a bit dry
22	1	1	20	stored	4	gold	3	4	4	2	2	3	The colour was beautiful pink, different sizes of portions smells similar to raw salmon, but that smell ‘appertises’ me. Texture was a little bit dry. Taste was typical lamb aroma
22	1	1	20	stored	5	gold	5	5	4	4	5	5	I could taste typical lamb, but was nice. The meat was so thin, so I think I can use for stir fry
22	1	1	20	stored	6	gold	5	5	5	5	4	5	I couldn’t smell typical lamb at all
22	1	1	20	stored	7	gold	4	5	5	4	5	4	I could smell a bit typical lamb. But texture was good. I think people who don’t like lamb would be able to eat this meat.
22	1	1	20	stored	8	gold	4	4	5	3	2	3	I didn’t like appearance of gristle. I couldn’t smell typical raw meat. Colour was beautiful. I could taste raw meat taste. The texture was tough because of gristle.
22	1	3	22	fresh cut	1	orange	4	4	4	5	5	5	Texture, I could feel like typical lamb
22	1	3	22	fresh cut	2	orange	4	5	5	5	5	5	Appearance looks beautiful. Portions are small and colour is shiny. Smells good, couldn't smell any bad smells. Taste good, easy to eat, little bit of fat in meat so texture was good.
22	1	3	22	fresh cut	3	orange	5	5	5	5	4	5	Looks uniform, very nice. Colour is beautiful but I could see blood on the meat. Could smell typical lamb, but it doesn’t mean it was smelly. Taste sweet and nice, texture was a little dry.
22	1	3	22	fresh cut	4	orange	4	4	2	3	3	3	Same as silver meat, looks beautiful. The colour I could see a little bit of dark colour in pink meat but it was shiny so colour doesn't look bad. I couldn't smell much but not bad smell. The meat was a little dry. When chewing could taste more typical lamb. Overall I was going to say slightly good but I changed my mind.
22	1	3	22	fresh	5	orange	5	5	4	4	4	4	It was delicious

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
				cut									
22	1	3	22	fresh cut	6	orange	3	3	4	3	3	3	
22	1	3	22	fresh cut	7	orange	5	5	5	5	5	5	When I put the meat in my mouth I could taste little bit typical lamb, but meat was sweet and tender and very delicious. I have never taste lamb like this before.
22	1	3	22	fresh cut	8	orange	5	5	4	4	5	5	Appearance was beautiful. Couldn't taste any raw meat. I was very surprised the meat was very tender. I thought this meat was delicious.
22	1	2	22	fresh cut	1	silver	4	4	3	5	5	4	Meat was tender, easy to eat
22	1	2	22	fresh cut	2	silver	5	5	5	5	4	5	Looks small portions, good for cooking. Appearance looks beautiful, the colour is shiny and very good. Smell was good, I couldn't smell any typical lamb smell. It was easy to eat, but little bit tougher than first (gold) meat
22	1	2	22	fresh cut	3	silver	5	5	5	4	5	5	Looks delicious, couldn’t smell much, taste a little sour but nice. Texture tender and nice
22	1	2	22	fresh cut	4	silver	5	4	4	1	2	2	Sizes are uniform looks beautiful. Colour was reddish pink, shiny, nice. Could smell fresh meat but first meat (gold) smell was stronger. Meat in mouth I could smell strong lam aroma, even when finished eating. The texture was dry. I was disappointed with taste because meat looked so beautiful.
22	1	2	22	fresh cut	5	silver	5	5	4	3	5	3	Smell is strong than gold one, cant eat lots of this meat
22	1	2	22	fresh cut	6	silver	4	4	5	5	5	5	
22	1	2	22	fresh cut	7	silver	4	5	4	2	5	4	Could see lots of gristle, I didn’t like the appearance, but the texture was good. Meat was tender, the smell was a bit too strong
22	1	2	22	fresh cut	8	silver	4	4	3	2	2	2	Appearance and colour just okay. I could smell typical raw meat more than gold meat. The taste also raw meat and dry it was not nice.
22	1	4	20	stored	1	white	4	4	5	5	5	5	Delicious, pity I wanted to add sauce
22	1	4	20	stored	2	white	5	5	5	5	5	5	Appearance is best of all today’s meat. Same portion sizes so looks beautiful. Colour is good and shiny. Smell is good but I could smell tiny bit typical lamb. Easy to eat and delicious, meat had a little fat = very tender

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
22	1	4	20	stored	3	white	4	5	4	3	3	3	Noticed gristle in meat, did not like. Looks nice. Good smell, typical lamb, doesn't mean smells bad. Couldn't taste much. Had gristle so couldn't chew. Meat was dry.
22	1	4	20	stored	4	white	2	2	2	5	5	4	The pieces were inconsistent and didn't look nice. The colour was a bit dark, I didn't think this looked good. The smell was too strong and sour, I didn't think it was a good smell. The texture was moist, I liked it. I can say it was delicious.
22	1	4	20	stored	5	white	5	5	4	5	5	5	I could taste fat so it was nice. Appearance also good after cooking
22	1	4	20	stored	6	white	3	2	3	2	2	2	Red colour was too dark
22	1	4	20	stored	7	white	5	5	4	4	5	4	I could smell little bit typical lamb but meat was tender and delicious
22	1	4	20	stored	8	white	4	3	2	1	1	1	Colour red was too dark. Could smell very strong raw meat. As soon as I put meat in my mouth I could taste typical lamb in whole mouth. I didn't like that.
36	2	4	34	stored	1	gold	3	4	3	5	2	3	Can't see any fat, very red. Could see a little bit of blood, which was not good. Can smell little bit typical meat. Was hard to chew
36	2	4	34	stored	2	gold	5	5	5	5	5	5	Well presented. Same size portions, which is very good. Easy to eat, taste good. Texture is good, easy to chew. Overall very good
36	2	4	34	stored	3	gold	3	5	4	1	1	1	Messy presentation, could see the blood in the packet which was not good. No smell, taste was sour, not a nice taste. Meat was dry and not nice. Overall not tasty at all
36	2	4	34	stored	4	gold	3	3	2	3	5	5	Looks like sizes are different, I didn't like the look of the gristle. The colour was not all the same, some was pink, some red, and some darker again. I could smell stronger smell than the other three. I didn't like this smell. Texture was the best. Taste also nice meat taste, and couldn't smell much in my mouth.
36	2	4	34	stored	5	gold	5	4	4	4	4	4	Texture was a bit hard to chew
36	2	4	34	stored	6	gold	2	2	3	4	3	3	Everything not too bad
36	2	4	34	stored	7	gold	5	5	5	4	5	4	As soon as I put the meat in my mouth, could smell typical lamb. Otherwise meat was tender and tasty.
36	2	4	34	stored	8	gold	3	2	2	3	2	3	Colour was a bit too dark, smell was strong, not very good. Texture was a little bit dry. I could smell typical lamb. I couldn't taste any sweetness.

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
36	2	4	34	stored	10	gold	5	5	5	5	5	5	The appearance is very good! All pieces are the same size and large pieces meal. The colour also very good which is light red. It is very good impression which is looked like good taste. Not a bad smell. Taste is very good, it is not oily and I feel it is very healthy meat. Texture also is soft. The impression of meat is very good.
36	2	4	34	stored	11	gold	4	5	5	3	4	4	Colour was good, but I could see some liquid from the meat so I just couldn't give a 'good' score. This meat didn't have nice meat taste than the other three.
36	2	2	36	fresh cut	1	orange	5	5	4	5	3	5	Looks like beef, and nice. Smells little bit of typical meat. If texture was a bit better, this meat would not be too bad.
36	2	2	36	fresh cut	2	orange	4	4	5	5	5	5	Less well presented compared to white. Colour is good, not shiny enough. Smells good. Taste was nice, and texture was also good
36	2	2	36	fresh cut	3	orange	5	5	5	4	4	4	Well presented. Colour looks tasty. Very nice smell. When I was chewing the taste got sour which is not good. Some parts of gristle I could not chew.
36	2	2	36	fresh cut	4	orange	5	5	3	3	3	3	(white) meat was beautiful, but this (orange) was more beautiful. Looks shiny, so before cooking already looks tasty. I could smell a faint sour smell. Smell was not good but not bad either. When I put meat in my mouth smell was really strong. Chewing later the smell was gone, I don’t dislike this taste.
36	2	2	36	fresh cut	5	orange	5	5	5	5	4	5	Easy to eat and tasty
36	2	2	36	fresh cut	6	orange	3	3	4	4	3	3	Appearance and colour was better than (white). The meat was well done, taste was better than (white). Texture was also better than (white), but still a little tough.
36	2	2	36	fresh cut	7	orange	4	5	5	5	5	5	Too much gristle, taste was delicious, I thought the meat had a seasoning. When I was chewing, I could smell typical meat, but I didn’t mind.
36	2	2	36	fresh cut	8	orange	3	3	3	5	5	4	Colour couldn’t tell if good or not. Could see the really thin meat very beautiful and fresh looking. I could smell little bit of typical lamb, but didn’t dislike the smell. Taste sweet and juicy and tender. It was delicious, I would like to eat this meat again.
36	2	2	36	fresh cut	10	orange	5	5	5	5	5	5	All of the pieces are the same size, which is good. The colour also very good. Smell is very good! Taste is very good, no bad smell, and a little oily.

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
													Texture was nice and soft. Overall the meat is very good.
36	2	2	36	fresh cut	11	orange	5	5	5	5	4	5	Colour and smell both really fresh, this is good. The (white) lamb was better taste, but texture was better with (orange)
36	2	3	36	fresh cut	1	silver	5	5	5	5	5	5	Meat was thin, looks good for cooking. Couldn't smell strong smell, which was good. Meat was tasty. After cooked looks good.
36	2	3	36	fresh cut	2	silver	4	5	5	5	5	5	Bit messy presentation, smells good. Was tasty. This one was a little bit oily. Easy to chew, which is good.
36	2	3	36	fresh cut	3	silver	5	5	5	3	3	3	Messy presentation. Colour looks nice. Smells sweet and tasty, really strong sour taste, overall texture was quite dry.
36	2	3	36	fresh cut	4	silver	5	4	4	2	4	4	The size is big, shiny. Looks tasty. Colour was a bit dark, but not a bad colour. Smells fresh. This meat cooked more rare then the other meat, so texture was very good and tasty. I think texture was better than taste. After finished eating, I could taste bitter.
36	2	3	36	fresh cut	5	silver	5	5	5	5	5	5	Very delicious
36	2	3	36	fresh cut	6	silver	3	3	4	4	2	3	Appearance, colour and smell very similar to orange sticker. This meat also cooked well done, o taste was good, but I didn't like the texture.
36	2	3	36	fresh cut	7	silver	5	5	5	5	5	5	I couldn't smell any typical lamb, meat was tender and delicious. Only when I chew the gristle that part was tough.
36	2	3	36	fresh cut	8	silver	3	3	3	5	4	4	Look, colour and smell all similar to (orange). I couldn't tell good or not good. Taste sweet, texture was a bit juicy, but orange was juicier. Was very tender and nice.
36	2	3	36	fresh cut	10	silver	4	5	5	5	5	5	Some of pieces are too large, if the meat put in package. The package is to large. The 'too large' package gives impression of low quality. Smell of meat is good. Taste is very good, it is not only texture is soft but also some pieces are good size. Overall it is good,
36	2	3	36	fresh cut	11	silver	5	5	5	5	4	5	Looks colour and texture all very similar to (orange).I could taste typical lamb, that I like. The person who doesn't like lamb should like this meat.
36	2	1	34	stored	1	white	4	4	4	4	4	4	Colour was a bit dark. Smells like jerky. Taste OK, but I didn't like the red juice that came out.

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
36	2	1	34	stored	2	white	5	5	5	5	4	4	Looks beautiful, well presented. I couldn't smell typical lamb smell, that is good. Easy to eat, taste nice. Texture was a little bit tough
36	2	1	34	stored	3	white	5	5	5	5	5	5	Colour looks nice. Smells sweet, could smell lamb. Sweet and tasty. Couldn't chew the gristle. Overall was tasty.
36	2	1	34	stored	4	white	5	5	4	3	2	2	When I saw the meat I thought it was a beautiful pink colour. Smells like raw salmon. Smells fresh. I could taste a little bit of sour. Texture was a bit dry. Looks beautiful, so was disappointed with texture. So I chose not very good for texture and overall.
36	2	1	34	stored	5	white	5	5	4	5	5	5	Taste typical lamb
36	2	1	34	stored	6	white	2	2	3	3	2	2	Some parts of the meat were tough. The colour was not very fresh
36	2	1	34	stored	7	white	5	5	5	4	5	5	I could smell a little bit typical lamb, but texture and taste was good. If the meat had a seasoning, maybe can cover typical lamb smell
36	2	1	34	stored	8	white	4	3	2	1	1	1	Looks shiny and beautiful, but colour was a bit too dark. Smells slightly old/off. Before I put the meat in my mouth, I didn't like the smell. Taste was bitter, not nice. Was really dry, I couldn't say anything was good.
36	2	1	34	stored	10	white	5	5	5	4	2	3	The appearance is very beautiful and colour is good. All of the slices are same colour. The meat has no bad smell. Taste and smell are very good. Little too oily, but texture was good.
36	2	1	34	stored	11	white	5	5	5	4	5	5	Colour and smell both very fresh, and good. It was very tender and taste nice. I like lamb meat, so I expected a bit of typical lamb taste. Lots of japanese people don't like lamb, but this meat is good for japanese people.
50	3	1	48	stored	1	gold	5	5	5	5	4	5	I like this meat, no problem at all.
50	3	1	48	stored	2	gold	4	5	4	5	5	4	Presentation not tidy. Smells typical lamb, but don't mind this smell. Taste was good, texture was not too tender, not too tough. Meat is good.
50	3	1	48	stored	3	gold	3	3	5	3	4	4	Colour was a bit too dark, so looks old meat. I could taste a little bit of sour, it was not nice. Texture was not too bad
50	3	1	48	stored	6	gold	3	3	4	2	2	2	Some meat looks so fresh, some of them not so fresh. Texture is a little bit tough, some strong smell left in my mouth.
50	3	1	48	stored	7	gold	5	5	3	5	5	5	Couldn't smell typical lamb, meat was tender, it was

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
													nice. Before cook, I could smell bit strong lamb smell.
50	3	1	48	stored	8	gold	3	3	2	4	3	3	Appearance and colour normal. Smell was very strong. Taste was not too bad. Texture was a little bit dry.
50	3	1	48	stored	10	gold	5	5	5	5	5	5	Some pieces are uniform and colour also good. No smell when raw. Taste is very good, it is similar to executive beef.
50	3	1	48	stored	11	gold	5	4	3	4	4	4	Bit of a strong smell, not typical lamb. I could taste typical lamb. I don’t think people who don’t like lamb would eat this
50	3	1	48	stored	12	gold	4	4	3	4	4	4	Couldn’t smell any typical lamb, I think this is a must for japanese people. Taste couldn’t smell any bad smell, very tender and easy to eat.
50	3	1	48	stored	13	gold	3	4	4	4	4	4	No smell. Easy to eat. Texture was similar to pork, which is good for Japanese.
50	3	4	50	fresh cut	1	orange	5	5	4	4	4	4	I wasn't satisfied with this meat
50	3	4	50	fresh cut	2	orange	4	5	5	4	4	4	Presentation was a bit messy. Couldn’t smell any typical lamb. When I was eating could smell a little lamb, was nice. Texture also not too tough which is good.
50	3	4	50	fresh cut	3	orange	5	5	5	5	5	5	Couldn’t see any dark colour so looks nice. I couldn’t smell any strong smell which is good. Taste sweet, good taste, typical lamb, which was nice. Texture was very tender. Overall very delicious.
50	3	4	50	fresh cut	6	orange	3	4	4	5	5	5	Texture was very tender and best of all sample. I couldn’t smell a bad smell at all
50	3	4	50	fresh cut	7	orange	4	5	5	5	5	5	Not bad smell at all. Meat was tender. Some meat was well done, so it thought it was seasoned. It was delicious.
50	3	4	50	fresh cut	8	orange	4	3	4	4	4	4	Same as (silver) meat, meat was shiny, but colour a little to dark. I couldn’t smell bad smell after being cooked. Meat was very sweet, nice but not juicy enough.
50	3	4	50	fresh cut	10	orange	5	5	5	5	5	5	There is much meat in package, it is good benefit for customers from meat. It is very good taste and texture, all meat have a bit oily and soft, all generation likes it. If possible, there is many pieces of meat in one package
50	3	4	50	fresh cut	11	orange	5	5	4	5	4	5	Colour looks pink and fresh.

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
50	3	4	50	fresh cut	12	orange	4	4	3	2	5	3	I cant tell difference between (gold)(silver) and (orange). No smell at all. Little bit of lamb smell near end of chewing.
50	3	4	50	fresh cut	13	orange	3	3	3	3	4	3	Meat colour was all different, which was not too good. Not too bad smell, but I have never smelled like this before. After cooked couldn't smell much, easy to eat
50	3	3	50	fresh cut	1	silver	4	5	4	5	5	5	Taste was so so
50	3	3	50	fresh cut	2	silver	5	5	5	3	4	3	Presentation was beautiful. Couldn't smell any bad smell. When I eat I could smell typical lamb. Lots of fat on meat.
50	3	3	50	fresh cut	3	silver	5	5	5	5	5	5	Looks nice presentation, was good, could see quite thick meat. Couldn't taste sour so was good. Texture was not tough so it was good.
50	3	3	50	fresh cut	6	silver	4	3	4	4	3	4	I couldn't smell at all, appearance looks beautiful
50	3	3	50	fresh cut	7	silver	5	5	5	5	5	5	Couldn't smell any bad smell. Meat was tender and delicious. When I put meat in my mouth I could taste little bit of salt, but after eating saltiness was good.
50	3	3	50	fresh cut	8	silver	4	4	4	5	4	5	Meat looks shiny and beautiful. Couldn't smell any bad smell. Meat was sweet. Texture was little bit tough, but it was tasty. When put meat in my mouth I couldn't smell at all
50	3	3	50	fresh cut	10	silver	5	5	5	4	4	4	Some meat have good balance between red and oil. Taste is better, after the meat is cooked, it is a bad smell. Texture was a bit hard.
50	3	3	50	fresh cut	11	silver	4	4	5	5	5	5	Colour didn't look fresh. Very mild smell. Taste was nice. This lamb would be good for stir fry.
50	3	3	50	fresh cut	12	silver	5	5	3	3	4	3	Looks nice and red and shiny, looks very tasty. Not much smell, so maybe japanese people like this. I could smell foam tray strongly. This meat was easy to eat, not like typical lamb at all
50	3	3	50	fresh cut	13	silver	5	5	4	5	4	4	May be too much fat in meat, but looks tasty. Smell no problem because not too strong, not too weak.
50	3	2	48	stored	1	white	4	4	4	3	4	4	I cant say if the taste is nice, if cooked with seasoning may be nicer.
50	3	2	48	stored	2	white	4	5	4	4	4	4	Presentation had gap between meat and didn't look good. Looks a little bit messy. I could smell a little bit of typical lamb. Taste also typical lamb, texture was bit tougher than (gold). I think because I chewed the gristle, meat was tender.

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
50	3	2	48	stored	3	white	4	4	5	4	3	4	Part I could see dark colour, but not whole of meat so I didn’t mind. I could taste a little bit of sour but I didn’t mind. There was some gristle I couldn't chew.
50	3	2	48	stored	6	white	2	2	2	2	2	2	After looked I could smell bad smell and meat was tough
50	3	2	48	stored	7	white	4	5	4	5	5	4	I could see too many gristles. Smell was a bit of an old meat smell. When I put in my mouth. I could smell tiny bit typical lamb, but I didn’t mind and tasted like had already been seasoned. Meat was tender and easy to eat.
50	3	2	48	stored	8	white	2	2	2	2	2	2	Colour was very dark red. Smells bad, quite strong and a little sour. Appearance and smell not very fresh. Taste was a little bitter, and could smell strong smell in my mouth & dry texture
50	3	2	48	stored	10	white	4	5	5	2	2	2	Some pieces are not uniform, which is not appealing. Taste is not good, it is very hard and feels like a bad smell after eating it. Texture is also not good.
50	3	2	48	stored	11	white	5	5	4	5	5	5	The colour looks very fresh. I couldn’t smell much meat but I could smell the tray. Taste was sweet and texture was not too tender, not too tough, just right.
50	3	2	48	stored	12	white	4	4	5	5	4	5	Stronger smell than others. I could taste typical lamb, and was quite tender. Easy to eat.
50	3	2	48	stored	13	white	5	5	2	2	4	3	Smell strong typical lamb, which I disliked. When I was chewing the meat I thought this meat is easier to eat than the others. Smells in mouth were stronger near the end, so taste was not good in the end
64	4	2	62	stored	1	gold	5	5	5	5	4	5	This meat is a bit better than (orange)
64	4	2	62	stored	2	gold	4	5	4	5	5	5	The meat was all on one side of the tray. Smelled more than the (orange). Meat was tender, when I was eating I could smell a bit, but taste was good.
64	4	2	62	stored	3	gold	5	5	5	4	5	5	Beautiful presentation. Looks and smells tasty. Little bit sour taste
64	4	2	62	stored	5	gold	5	4	4	5	5	5	It was very tasty. Thickness is just right.
64	4	2	62	stored	8	gold	5	5	5	5	5	5	Bit oily, is feel healthy meat.
64	4	2	62	stored	10	gold	3	4	2	3	3	3	Beautiful colour, but not shiny enough. A little bit of a sour smell. When I was eating I couldn’t smell much. Not enough juiciness, was a bit dry.
64	4	2	62	stored	11	gold	5	5	5	4	4	5	Not enough redness, but very shiny which is good. Easy to eat. Texture was just right

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
64	4	2	62	stored	14	gold	5	5	2	2	2	3	I could smell a little bit, I could feel gristle in my mouth
64	4	2	62	stored	15	gold	5	5	3	4	5	4	Appearance is very beautiful so I thought I wanted to buy this meat. Tender and easy to eat, might be too easy to eat. I want a little more meat taste.
64	4	2	62	stored	16	gold	4	4	3	2	3	3	
64	4	1	64	fresh cut	1	orange	5	5	5	5	4	5	The texture a little bit tough
64	4	1	64	fresh cut	2	orange	5	5	5	5	5	5	Very neat presentation. Colour very shiny and good. No smell which is good. Easy to eat and nice.
64	4	1	64	fresh cut	3	orange	4	5	5	5	5	5	Sizes are different, small pieces of meat were too small. Was tasty and tender
64	4	1	64	fresh cut	5	orange	4	4	3	3	2	3	Texture was not too good. Hard to chew, meat is dry which is not too good
64	4	1	64	fresh cut	8	orange	5	5	5	5	5	5	The meat does not smell bad. Good sized pieces. Colour red is good. The meat is very soft and not oily, it is very healthy. It is best choice for customers to take to a korean bbq.
64	4	1	64	fresh cut	10	orange	3	4	2	4	5	4	Beautiful colour, but not shiny enough. Smells very strong, sweet taste but too strong smell. I could eat it if had strong condiments. Meat juicy so overall not too bad.
64	4	1	64	fresh cut	11	orange	5	5	5	4	5	5	Appearance and colour very fresh. Easy to eat. Appearance colour and smell was fresh. Easy to eat, I could notice a little bit of gristle
64	4	1	64	fresh cut	14	orange	4	5	4	5	5	5	Meat was tender, couldn't smell much so was easy to eat
64	4	1	64	fresh cut	15	orange	4	5	3	5	5	5	Appearance and colour was beautiful, the meat was too thin. Texture was tender, not much smell and easy to eat. Overall taste nice
64	4	1	64	fresh cut	16	orange	5	4	3	5	5	4	
64	4	4	64	fresh cut	1	silver	4	5	5	5	5	5	This was the best. Very tasty.
64	4	4	64	fresh cut	2	silver	5	5	5	5	5	5	Beautiful presentation. The colour was good and shiny, smells good too. Couldn't smell while eating. Texture was good and it was very tasty.
64	4	4	64	fresh cut	3	silver	5	5	5	5	5	5	Beautiful presentation. Looks and smells tasty. Not very sour, was good and tasty. Easy to chew, so tender.
64	4	4	64	fresh cut	5	silver	4	4	4	5	4	5	The thickness is just right and meat was a little dry

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
64	4	4	64	fresh cut	8	silver	5	5	5	5	5	5	It is very soft for people especially older or infant to eat it.
64	4	4	64	fresh cut	10	silver	3	2	3	5	4	4	Colour similar to (white), not fresh enough. I could smell a little bit but very tasty. Quite juicy which is good
64	4	4	64	fresh cut	11	silver	5	5	5	5	5	5	Not enough redness, but shiny which is good. Easy to eat. Texture was just right.
64	4	4	64	fresh cut	14	silver	2	4	3	4	4	4	Some part of meat was tough. But quite juicy meat.
64	4	4	64	fresh cut	15	silver	5	4	3	4	5	4	This meat has strongest smell and taste. Meat was tender, texture was just right so it was nice. After finished eating could smell typical lamb in my mouth.
64	4	4	64	fresh cut	16	silver	4	4	2	3	3	3	
64	4	3	62	stored	1	white	5	5	5	5	4	5	If someone asked me if this meat was tasty I could say yes
64	4	3	62	stored	2	white	4	5	5	5	5	5	Looks a bit messy. Colour is good and shiny, couldn't smell which is good. Texture was good, taste was nice.
64	4	3	62	stored	3	white	4	5	5	4	4	4	Not very good presentation. Sizes are different. Looks and smells tasty. Little bit sour, but it was tasty.
64	4	3	62	stored	5	white	4	4	4	4	2	3	Meat was tough, hard to chew and very dry
64	4	3	62	stored	8	white	5	5	5	5	5	5	It is very good BBQ met. There are many pieces in the package, therefore many people will buy it.
64	4	3	62	stored	10	white	3	2	3	4	2	3	Colour was not fleshy enough. Couldn't see nice pink. The smell, I could smell a little bit but I didn't mind. Taste easy to eat, but not enough juiciness a little bit dry.
64	4	3	62	stored	11	white	5	5	5	4	4	4	Very fresh red meat colour, beautiful colour. No smell. I could smell foam container because no seasoning. After cooked I could taste a little bit of container, but couldn't smell it. The meat was a little tough.
64	4	3	62	stored	14	white	4	4	3	2	1	2	Meat is tough with lots of gristle. Not enough juiciness
64	4	3	62	stored	15	white	4	4	3	5	4	4	The appearance and taste I could feel not too expensive meat because too much gristle. Texture quite chewy so it took a long time to finish eating.
64	4	3	62	stored	16	white	4	4	2	4	4	4	After cooked, I could smell it in my mouth
78	5	4	76	stored	1	gold	5	5	5	5	5	5	It was tasty

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
78	5	4	76	stored	2	gold	5	5	4	3	5	3	Beautiful presentation, pieces same sizes which is good. Colour is good and shiny. I could smell a little bit typical lamb. This meat was not easy to eat. Strong typical lamb smell
78	5	4	76	stored	3	gold	5	4	1	3	5	3	Colour has changed. I could smell bad smell. It was not very nice. Texture was tender which is good. Not very tasty, so I didn't really want to eat it.
78	5	4	76	stored	5	gold	4	4	2	5	5	4	I didn't like, some meat was rare, but this meat was better than other 3
78	5	4	76	stored	8	gold	5	2	4	1	2	2	Could taste bitter after cooked very strong smell. Couldn't get rid of smell.
78	5	4	76	stored	10	gold	4	5	5	5	5	5	The meat sizes in the package were too random. Was not appealing The texture was the softest of the other meat. The taste was also very good because the meat was not oily. The image of lamb is not good for Japanese people such as bad smell and not good taste. However, these meats in this day are very good and will become very popular in near future
78	5	4	76	stored	11	gold	5	5	5	2	5	3	Colour is good, couldn't smell much. After cooking there was a strong smell, it was not nice. Texture was tender and good.
78	5	4	76	stored	12	gold	5	5	4				Appearance and colour both good. Smells not too bad. I don't think Japanese people can tell this is lamb from the smell. It was really simple taste compared to the other three meat. Texture was very good. It was nice
78	5	4	76	stored	14	gold	3	4	2	2	4	2	Not shiny enough, but colour is beautiful, smells a little bit sour. Meat was tender. When I was eating the meat I could smell a bad smell which was not good. Taste was not good.
78	5	4	76	stored	15	gold	4	5	3	4	5	4	Appearance, this size of meat is good for many kinds of cooking. Different sizes which is not too good. If sauce sizes looks more expensive meat. I could smell typical raw meat. Texture very tender. I could taste a bit of bitter.
78	5	2	78	fresh cut	1	orange	4	4	5	5	4	5	A little bit tough
78	5	2	78	fresh cut	2	orange	5	5	5	5	5	5	Beautiful presentation. No bad smell at all which is very good. Couldn't smell while chewing which is good. Texture was tender and very delicious.
78	5	2	78	fresh cut	3	orange	2	5	5	5	5	5	Different sizes, not very good presentation, so didn't look good. Looks delicious. Smells sweet. Not

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
													sour at all, it was nice, actually sweet. Very tender.
78	5	2	78	fresh cut	5	orange	4	4	5	5	4	4	The smell was not too strong, not as strong as 2 weeks ago. The texture was good because meat is very thin.
78	5	2	78	fresh cut	8	orange	4	3	3	5	5	5	Very tender and tasty
78	5	2	78	fresh cut	10	orange	5	5	5	5	5	5	Some pieces are the same size and very beautiful. The package is more heavy than the first (silver) package. The texture is more soft than first (silver). Many Japanese people like soft meat and a little oily meat. Because, they would like to become healthy.
78	5	2	78	fresh cut	11	orange	5	5	5	4	4	5	Colour and smell both fresh. Easy to eat because no gristle. Taste also good
78	5	2	78	fresh cut	12	orange	5	5	5	5	5	5	This meat is darker colour than the other meat (silver). They don’t look like lamb meat. It could smell slightly lam smell which is good. Taste and texture both good, it was tasty. I didn’t think this was lamb
78	5	2	78	fresh cut	14	orange	4	3	3	3	3	3	Very shiny, so appearance is good. Taste was nice but after finished eating the smell was left in my mouth. This meat was drier than the others
78	5	2	78	fresh cut	15	orange	5	5	5	3	5	4	Very good presentation. Right thickness and size. I felt I would want to buy this meat. Texture was very good and tender, but I didn’t like the taste because it was a bit bitter. If this meat didn’t have the bitterness it would have been perfect.
78	5	1	78	fresh cut	1	silver	5	5	5	5	5	5	It was tasty
78	5	1	78	fresh cut	2	silver	5	5	4	4	5	4	Presentation was the right thickness, just right which is very good. I could smell little bit strong meat, but I didn’t mind the smell. I could smell a little bit in my mouth but I didn’t mind. Texture was good and overall was good
78	5	1	78	fresh cut	3	silver	5	5	5	4	4	4	Looks delicious, colour looks delicious. Could smell typical lamb smell. Bit of a sour taste. Meat was a little dry but tasty. I couldn’t see any gristle which is good.
78	5	1	78	fresh cut	5	silver	4	4	4	3	2	3	Hard to chew. Texture not too good. But when I put it in my mouth it was tasty. I didn’t like, I could see rare meat after being cooked.
78	5	1	78	fresh cut	8	silver	4	5	4	4	3	4	It was juicy which is good

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
78	5	1	78	fresh cut	10	silver	5	5	5	4	4	4	Some meat are the same size, it is very beautiful. If possible wish some pieces are more large. In addition it is more pieces of meat in package. Big package and much pieces are feel like like benefit from meat. The grilled meat is hard. The hard meat is not like for elder people. Healthy meat is liked by them because its a little oily. However the texture is hard which is not very good for them
78	5	1	78	fresh cut	11	silver	5	5	3	2	4	3	Colour is just right, looks fresh. I could smell a little bit of a strong smell. Texture was good, but I could taste blood. Even after I finished eating I could still taste a bad taste left in my mouth
78	5	1	78	fresh cut	12	silver	5	5	5	5	5	5	Looks good, colour is good. Smells not typical lamb, so was appetising. It was delicious. Texture good. Normally Japanese don’t like lamb, but think Japanese could eat this product.
78	5	1	78	fresh cut	14	silver	3	2	2	4	3	4	The colour was a little bit too dark. I could smell very strong smell. But after cooked I couldn’t smell much. Not too bad taste. A little dry but not too bad.
78	5	1	78	fresh cut	15	silver	4	4	4	5	5	4	Portions too small, should be about 2x larger. Texture was good, tender, easy to eat. It was tasty
78	5	3	76	stored	1	white	5	5	5	5	5	5	It was tasty
78	5	3	76	stored	2	white	5	5	3	5	5	4	Beautiful presentation, colour is very good and shiny. This meat has a little bit of a strong smell. Taste no smell, it was nice. Not tough at all, easy to eat.
78	5	3	76	stored	3	white	5	4	2	2	5	2	Colour has changed. I couldn't smell typical lamb, I could smell bad smell. Little bit bitter, so it was not very nice. Texture not too bad. It was not nice, so I couldn’t eat much
78	5	3	76	stored	5	white	2	3	3	5	4	5	Colour is very dark, looks like liver. Before being cooked the appearance is not too good. Texture was very good, it was tasty, but I didn’t like some meat as some was a little undercooked.
78	5	3	76	stored	8	white	2	5	5	3	1	2	I didn’t like the gristle. Texture was very bad. I could feel gristle, very hard.
78	5	3	76	stored	10	white	4	5	5	5	5	5	The size of meat are random which are putting small and large meat mixed in the package. It is not beautiful. The marketing of meat package are very important for general people to put in the same size meat in package. The texture is very soft. Many Japanese people like it. It is almost perfect but the package is not better, if possible, please put pieces

Age	Session	Order	Cut.on	Storage	Tester	Sample	Appearance	Colour	Smell	Taste	Texture	Overall	Comment
													of meat the same size.
78	5	3	76	stored	11	white	4	3	2	2	5	3	The colour was not fresh red, didn't look as fresh as other meat. Strong smell. Not very good smell Texture was tender and good, but taste was not good. Worst taste compared to other meat. But if it had sauce on it I could eat it.
78	5	3	76	stored	12	white	3	3	3	5	5	5	Appearance and colour both not too bad but compared to (silver) and (orange) was not appetising. Much stronger smell, which I didn't mind but don't know for other Japanese people. After cooked, no smell at all, it was tasty. So overall I thought it was very good.
78	5	3	76	stored	14	white	3	3	2	3	4	4	Not shiny, the colour was too dark. Smells sour, but after cooked no smell and meat was juicy and tasty
78	5	3	76	stored	15	white	4	5	5	5	5	5	Appearance and colour both good and shiny, right size. Could see a lot of gristle, but it was very tasty. Texture was good, not strong typical lamb taste. This meat was the best

9.5 Appendix 5: Statistical Analyses

```
> library(car)
> plot.height <- 4
> plot.width <- 6
> plot.height2 <- 4
> plot.width2 <- 6

> ## ---------------------------------------------------------------------
> ## Data Import and manipulation:
> ## ---------------------------------------------------------------------
>
> ## Notes: Gold and White were replicates: cut 2 days prior to sensory
> ## Similarly, Orange and Silver were replicates: cut on the day of sensory.
> ## Import and manipulate the Sensory data
> ## Notes:
> ## * age was based on product having been produced on 30/09/2009
> Sensory <- read.csv("../data/sensory.csv", header=TRUE, as.is=TRUE)
> Sensory$comment <- NULL ## comments not needed for the analysis
> Sensory <- transform(Sensory,
+                     session=factor(session),
+                     storage=factor(storage),
+                     tester=factor(tester),
+                     sample=factor(sample, levels=c("gold", "white", "silver",
"orange")))

> ## Import and manipulate the Micro data
> ## Notes:
> ## * age was based on all product having been produced on 30/09/2009 at 09:00
> Micro <- read.csv("../data/micro.csv", header=TRUE, as.is=TRUE)
> Micro$collect.date <- NULL
> Micro$collect.time <- NULL
> Micro$collect <- NULL
> Micro$test.date <- NULL
> Micro$test.time <- NULL

> ## Split the micro data into two - surface slices sampled directly from the
> ## vacuum packed meat and the sliced product packaged in trays.
> Micro.pieces <- subset(Micro, sample.type=="pieces")
> Micro.pieces$sample.type <- NULL
> Micro.pieces$storage <- NULL
> Micro.pieces <- transform(Micro.pieces,
+                          sample=factor(sample, levels=c("gold", "white", "silver",
"orange")))

> Micro.slices <- subset(Micro, sample.type=="slices")
> Micro.slices$sample.type <- NULL
> Micro.slices <- transform(Micro.slices,
+                          storage=factor(storage),
+                          session=factor(session),
+                          sample=factor(sample, levels=c("gold", "white", "silver",
"orange")))

> ## ---------------------------------------------------------------------
> ## Microbiology:
> ## ---------------------------------------------------------------------
>
> ## **************************************************
> ## Pieces sampled directly after opening vacuum packs
> ## **************************************************
>
> ## Aerobic Plate Count Plot over time
> win.metafile(file="../graphics/apc_pieces.wmf", width=plot.width,
+              height=plot.height)
> print(xyplot(log10(apc) ~ age, groups=sample, data=Micro.pieces,
+              xlim=c(18,82), ylim=c(1.5,8.5), col=1, pch=20,
+              xlab="Storage time (days)",
+              ylab=expression(paste("log"[10]," APC (cfu/g)")),
+              panel=function(x,y,...){
+                panel.grid(h=-1,v=-1)
+                panel.superpose(x,y,...)
+                ## panel.abline(coef(lm1.apc))
+              }))
> dev.off()
null device
          1
```

```
> ## Clearly growth doesn't happen throughout the whole storage time, but only
> ## during over the first three session (approximately). By the time 50 days
> ## comes around it looks like we've hit stationary phase.  Let's fit a straight
> ## line to the first six times, that is, up to age 50.
> lm1.apc <- lm(log10(apc) ~ age, data=Micro.pieces, subset=age<55)
> summary(lm1.apc)

Call:
lm(formula = log10(apc) ~ age, data = Micro.pieces, subset = age <
    55)

Residuals:
     Min       1Q   Median       3Q      Max
-1.07010 -0.43162  0.04014  0.27141  0.92725

Coefficients:
            Estimate Std. Error t value         Pr(>|t|)
(Intercept)  0.35041    0.38283   0.915             0.37
age          0.15043    0.01036  14.523 0.00000000000094

Residual standard error: 0.5826 on 22 degrees of freedom
Multiple R-squared: 0.9055,      Adjusted R-squared: 0.9013
F-statistic: 210.9 on 1 and 22 DF,  p-value: 0.0000000000009395


> ## Residual plot doesn't look great, but we've got few data points. And any
> ## temperature fluctuations may have an impact on what we might see.
> par(mfrow=c(2,2))
> plot(lm1.apc, which=c(1,3,5))
> qq.plot(resid(lm1.apc),col="black")

> ## Lactic Acid Plot over time
> win.metafile(file="../graphics/lab_pieces.wmf", width=plot.width,
+              height=plot.height)
> print(xyplot(log10(lab) ~ age, groups=sample, data=Micro.pieces,
+              xlim=c(18,82), ylim=c(1.5,8.5), col=1, pch=20,
+              xlab="Storage time (days)",
+              ylab=expression(paste("log"[10]," LAB (cfu/g)")),
+              panel=function(x,y,...){
+                panel.grid(h=-1,v=-1)
+                panel.superpose(x,y,...)
+                ## panel.abline(coef(lm1.lab))
+              }))
> dev.off()
null device
          1

> ## Same comments as for APC apply here.
> lm1.lab <- lm(log10(lab) ~ age, data=Micro.pieces, subset=age<55)
> summary(lm1.lab)

Call:
lm(formula = log10(lab) ~ age, data = Micro.pieces, subset = age <
    55)

Residuals:
      Min        1Q    Median        3Q       Max
-1.280749 -0.201330  0.009572  0.322921  1.299517

Coefficients:
            Estimate Std. Error t value          Pr(>|t|)
(Intercept)  -0.3456     0.3919  -0.882             0.387
age           0.1576     0.0106  14.858 0.000000000000594

Residual standard error: 0.5964 on 22 degrees of freedom
Multiple R-squared: 0.9094,      Adjusted R-squared: 0.9053
F-statistic: 220.8 on 1 and 22 DF,  p-value: 0.0000000000005944

> ## Look reasonably OK. Some bumping around even within a couple of
> ## days, but that could be expected since they are different shoulders
> par(mfrow=c(2,2))
> plot(lm1.lab, which=c(1,3,5))
> qq.plot(resid(lm1.lab),col="black")
> ## A couple of the smallest residuals are a bit too low. Doesn't appear too
> ## major though, especially, given the sample size.
```

```
> ## **************************************************
> ## Slices sampled as part of sensory evaluation -
> ## stored 0 or 2 days
> ## **************************************************
>
> ## Aerobic Plate Count Plot over time
> win.metafile(file="../graphics/apc_slices.wmf", width=plot.width,
+              height=plot.height)
> print(xyplot(log10(apc) ~ age, groups=storage, data=Micro.slices,
+              xlim=c(18,82), ylim=c(1.8, 8.5),
+              xlab="Storage time (days)",
+              ylab=expression(paste("log"[10]," APC (cfu/g)")),
+              col=c("red","black"), pch=c(20,18),
+              panel=function(x,y,...){
+                panel.grid(h=-1,v=-1)
+                panel.superpose(x,y,...)
+                panel.text(x=25, y=2.5, adj=0, col="red", label="fresh cut")
+                panel.text(x=25, y=4.5, adj=0, col="black", label="stored")
+              }))
> dev.off()
null device
          1

> ## Let's fit a model that takes each session separately and fits an effect for
> ## stored versus freshly cut.
> lm2.apc <- lm(log10(apc) ~ session * storage, data=Micro.slices)
> Anova(lm2.apc, type="II")
Anova Table (Type II tests)

Response: log10(apc)
                 Sum Sq Df  F value  Pr(>F)
session         168.665  4 292.2573 < 2e-16
storage          24.563  1 170.2455 < 2e-16
session:storage   2.338  4   4.0517 0.00637
Residuals         7.214 50

> summary(lm2.apc)

Call:
lm(formula = log10(apc) ~ session * storage, data = Micro.slices)

Residuals:
     Min       1Q   Median       3Q      Max
-0.63455 -0.19507 -0.01310  0.15607  0.80118

Coefficients:
                       Estimate Std. Error t value       Pr(>|t|)
(Intercept)              2.7095     0.1551  17.473         < 2e-16
session2                 1.3128     0.2193   5.986 0.0000002298144
session3                 4.7945     0.2193  21.863         < 2e-16
session4                 3.7338     0.2193  17.026         < 2e-16
session5                 3.9665     0.2193  18.087         < 2e-16
storagestored            1.9072     0.2193   8.697 0.0000000000142
session2:storagestored  -0.8009     0.3101  -2.582        0.012789
session3:storagestored  -1.1266     0.3101  -3.632        0.000661
session4:storagestored  -0.8349     0.3101  -2.692        0.009636
session5:storagestored  -0.3754     0.3101  -1.211        0.231757

Residual standard error: 0.3798 on 50 degrees of freedom
Multiple R-squared: 0.9644,     Adjusted R-squared: 0.958
F-statistic: 150.6 on 9 and 50 DF,  p-value: < 2.2e-16

> ## Looks OK.
> par(mfrow=c(2,2))
> plot(lm2.apc, which=c(1,3,5))
> qq.plot(resid(lm2.apc),col="black")

> ## A few of the residuals our out, but we could see that some of the results
> ## were just a bit more variable than expected.
```

```
> ## What about the average storage effect?
> lm2a.apc <- lm(log10(apc) ~ session + storage, data=Micro.slices)
> summary(lm2a.apc)

Call:
lm(formula = log10(apc) ~ session + storage, data = Micro.slices)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.87713 -0.19673  0.01656  0.27644  0.87318 

Coefficients:
              Estimate Std. Error t value   Pr(>|t|)
(Intercept)     3.0233     0.1330  22.731    < 2e-16
session2        0.9124     0.1717   5.314 0.00000209
session3        4.2312     0.1717  24.642    < 2e-16
session4        3.3163     0.1717  19.314    < 2e-16
session5        3.7787     0.1717  22.007    < 2e-16
storagestored   1.2797     0.1086  11.784    < 2e-16

Residual standard error: 0.4206 on 54 degrees of freedom
Multiple R-squared: 0.9529,      Adjusted R-squared: 0.9485 
F-statistic: 218.5 on 5 and 54 DF,  p-value: < 2.2e-16 

> ## Lactic Acid Plot over time
> win.metafile(file="../graphics/lab_slices.wmf", width=plot.width,
+              height=plot.height)
> print(xyplot(log10(lab) ~ age, groups=sample, data=Micro.slices,
+              xlim=c(18,82), ylim=c(1.8, 8.5),
+              xlab="Storage time (days)",
+              ylab=expression(paste("log"[10]," LAB (cfu/g)")),
+              col=c(1,1,2,2), pch=c(18,18,20,20),
+              panel=function(x,y,...){
+                panel.grid(h=-1,v=-1)
+                panel.superpose(x,y,...)
+                panel.text(x=25, y=2.5, adj=0, col="red", label="fresh cut")
+                panel.text(x=25, y=4.5, adj=0, col="black", label="stored")
+              }))
> dev.off()
null device 
          1 

> ## Let's fit a model that takes each session separately and fits an effect for
> ## stored versus freshly cut. Difference between stored and fresh cut is
> ## consistent across session.
> lm2.lab <- lm(log10(lab) ~ session * storage, data=Micro.slices)
> Anova(lm2.lab, type="II")
Anova Table (Type II tests)

Response: log10(lab)
                 Sum Sq Df  F value    Pr(>F)
session         166.095  4 321.6969 < 2.2e-16
storage          16.702  1 129.3976  4.26e-15
session:storage   1.052  4   2.0368    0.1045
Residuals         6.067 47                   

> lm2a.lab <- lm(log10(lab) ~ session + storage, data=Micro.slices)
> summary(lm2a.lab)

Call:
lm(formula = log10(lab) ~ session + storage, data = Micro.slices)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.80661 -0.20455 -0.06517  0.27257  0.88872 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)    2.88511    0.11867  24.311  < 2e-16
session2       0.92149    0.15252   6.042 1.76e-07
session3       4.12067    0.15252  27.017  < 2e-16
session4       3.32701    0.15996  20.798  < 2e-16
session5       3.95704    0.15601  25.364  < 2e-16
storagestored  1.08350    0.09905  10.939 5.53e-15

Residual standard error: 0.3736 on 51 degrees of freedom
  (3 observations deleted due to missingness)
```

```
Multiple R-squared: 0.9622,      Adjusted R-squared: 0.9585
F-statistic: 259.6 on 5 and 51 DF,  p-value: < 2.2e-16

> ## Looks OK.
> par(mfrow=c(2,2))
> plot(lm2.lab, which=c(1,3,5))
> qq.plot(resid(lm2.lab),col="black")
> ## A few of the residuals our out, but we could see that some of the results
> ## were just a bit more variable than expected.

> ## ----------------------------------------------------------------------
> ## Sensory Analysis:
> ## ----------------------------------------------------------------------

> ## Appearance
> ## ==========
> win.metafile(file="../graphics/appearance_hist.wmf", width=plot.width2,
+              height=plot.height2)
> print(histogram(~appearance | session + storage, data=Sensory, as.table=TRUE,
+                 breaks=(0:5+0.5), type="count", ylim=c(0,15),
+                 xlab="Appearance Score", ylab="Number of responses",
+                 scales=list(alternating=FALSE),
+                 panel=function(x,...){
+                   smy <- summary(x)
+                   panel.grid(-1,-1)
+                   panel.histogram(x,...)
+                   panel.text(0.5,14,paste("Median =",smy[3]),adj=0,cex=0.7)
+                   panel.text(0.5,12.5,paste("Mean =",smy[4]),adj=0,cex=0.7)
+                   panel.text(0.5,11,paste("St Dev =",round(sd(x),2)),adj=0,cex=0.7)
+                 },
+                 strip=strip.custom(strip.levels=c(TRUE,TRUE),
+                   par.strip.text=list(cex=0.75))
+                 ))
> dev.off()
null device
          1

> ## Fit a model which takes into account a different baseline per panellist
> ## (tester). Allows for a difference between storage duration and the order of
> ## tasting (and their interaction), and finally allows for different aged meat
> ## (different animals) to have different average scores.
> fit.app1 <- lm(appearance ~ tester + storage*factor(age) + storage*order,
data=Sensory)
> Anova(fit.app1, type="II")
Anova Table (Type II tests)

Response: appearance
                    Sum Sq  Df F value      Pr(>F)
tester              35.843  14  4.3643 0.000001367
storage              2.755   1  4.6967     0.03165
factor(age)          1.514   4  0.6454     0.63089
order                2.627   1  4.4774     0.03584
storage:factor(age)  3.257   4  1.3880     0.24028
storage:order        0.075   1  0.1283     0.72066
Residuals           97.380 166

> par(mfrow=c(2,2))
> plot(fit.app1, which=c(1,3,5))
> qq.plot(resid(fit.app1),col="black")

> fit.app2 <- update(fit.app1, .~. - storage:order)
> Anova(fit.app2, type="II")
Anova Table (Type II tests)

Response: appearance
                    Sum Sq  Df F value      Pr(>F)
tester              35.843  14  4.3872 0.000001226
storage              2.755   1  4.7213     0.03120
factor(age)          1.401   4  0.6003     0.66290
order                2.627   1  4.5009     0.03535
storage:factor(age)  3.362   4  1.4403     0.22289
Residuals           97.455 167
```

```
> fit.app3 <- update(fit.app2, .~. - storage:factor(age))
> Anova(fit.app3, type="II")
Anova Table (Type II tests)

Response: appearance
             Sum Sq  Df F value    Pr(>F)
tester       35.843  14  4.3425 0.0000014
storage       2.755   1  4.6732   0.03203
factor(age)   1.401   4  0.5942   0.66728
order         1.134   1  1.9241   0.16722
Residuals   100.817 171

> fit.app4 <- update(fit.app3, .~. - factor(age))
> Anova(fit.app4, type="II")
Anova Table (Type II tests)

Response: appearance
           Sum Sq  Df F value      Pr(>F)
tester     35.345  14  4.3222 0.000001449
storage     2.755   1  4.7170     0.03121
order       1.134   1  1.9421     0.16521
Residuals 102.219 175

> fit.app5 <- update(fit.app4, .~. - order)
> Anova(fit.app5, type="II")
Anova Table (Type II tests)

Response: appearance
           Sum Sq  Df F value      Pr(>F)
tester     35.345  14  4.2992 0.000001577
storage     2.755   1  4.6918     0.03165
Residuals 103.353 176

> summary(fit.app5)

Call:
lm(formula = appearance ~ tester + storage, data = Sensory)

Residuals:
     Min       1Q   Median       3Q      Max
-2.51979 -0.49479  0.06771  0.51979  2.03646

Coefficients:
              Estimate Std. Error t value   Pr(>|t|)
(Intercept)    4.61979    0.18006  25.658    < 2e-16
tester2        0.10000    0.24233   0.413    0.68036
tester3       -0.10000    0.24233  -0.413    0.68036
tester4       -0.50000    0.32057  -1.560    0.12062
tester5       -0.06250    0.25703  -0.243    0.80816
tester6       -1.41667    0.27982  -5.063 0.00000103
tester7        0.08333    0.27982   0.298    0.76620
tester8       -0.60000    0.24233  -2.476    0.01423
tester10      -0.25000    0.25703  -0.973    0.33206
tester11       0.31250    0.25703   1.216    0.22568
tester12      -0.12500    0.32057  -0.390    0.69706
tester13      -0.50000    0.41973  -1.191    0.23516
tester14      -1.00000    0.32057  -3.119    0.00212
tester15      -0.12500    0.32057  -0.390    0.69706
tester16      -0.25000    0.41973  -0.596    0.55219
storagestored -0.23958    0.11061  -2.166    0.03165

Residual standard error: 0.7663 on 176 degrees of freedom
Multiple R-squared: 0.2693,      Adjusted R-squared: 0.2071
F-statistic: 4.325 on 15 and 176 DF,  p-value: 0.0000007582

> par(mfrow=c(2,2))
> plot(fit.app5, which=c(1,3,5))
> qq.plot(resid(fit.app5),col="black")
> ## Some kinks, but nothing dramatic.

> ## Now obtain the means for each factor
> mt.app.m <- model.tables(aov(appearance ~ tester + storage, data=Sensory),
+                          type="mean")

> summary(predict(fit.app5)) ## Check the fit - don't want too many above 5
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  2.964   4.120   4.370   4.266   4.557   4.932
```

```
> round(mt.app.m$tables[[3]],1)
storage
fresh cut    stored
      4.4       4.1

> ## Colour
> ## ==========
> win.metafile(file="../graphics/colour_hist.wmf", width=plot.width2,
+              height=plot.height2)
> print(histogram(~colour | session + storage, data=Sensory, as.table=TRUE,
+                 breaks=(0:5+0.5), type="count", ylim=c(0,15),
+                 xlab="Colour Score", ylab="Number of responses",
+                 scales=list(alternating=FALSE),
+                 panel=function(x,...){
+                   smy <- summary(x)
+                   panel.grid(-1,-1)
+                   panel.histogram(x,...)
+                   panel.text(0.5,14,paste("Median =",smy[3]),adj=0,cex=0.7)
+                   panel.text(0.5,12.5,paste("Mean =",smy[4]),adj=0,cex=0.7)
+                   panel.text(0.5,11,paste("St Dev =",round(sd(x),2)),adj=0,cex=0.7)
+                 },
+                 strip=strip.custom(strip.levels=c(TRUE,TRUE),
+                   par.strip.text=list(cex=0.9))
+                 ))
> dev.off()
windows
      2

> ## Fit a model which takes into account a different baseline per panellist
> ## (tester). Allows for a difference between storage duration and the order of
> ## tasting (and their interaction), and finally allows for different aged meat
> ## (different animals) to have different average scores.
> fit.col1 <- lm(colour ~ tester + storage*factor(age) + storage*order, data=Sensory)
> Anova(fit.col1, type="II")
Anova Table (Type II tests)

Response: colour
                    Sum Sq  Df F value             Pr(>F)
tester              56.276  14  7.6661 0.000000000002527
storage              2.521   1  4.8075           0.02973
factor(age)          1.560   4  0.7437           0.56351
order                3.306   1  6.3054           0.01299
storage:factor(age)  2.565   4  1.2228           0.30312
storage:order        0.075   1  0.1435           0.70528
Residuals           87.042 166

> par(mfrow=c(2,2))
> plot(fit.col1, which=c(1,3,5))
> qq.plot(resid(fit.col1),col="black")

> fit.col2 <- update(fit.col1, .~. - storage:order)
> Anova(fit.col2, type="II")
Anova Table (Type II tests)

Response: colour
                    Sum Sq  Df F value             Pr(>F)
tester              56.276  14  7.7056 0.000000000002089
storage              2.521   1  4.8323           0.02931
factor(age)          1.501   4  0.7195           0.57974
order                3.306   1  6.3379           0.01276
storage:factor(age)  2.681   4  1.2850           0.27794
Residuals           87.117 167

> fit.col3 <- update(fit.col2, .~. - storage:factor(age))
> Anova(fit.col3, type="II")
Anova Table (Type II tests)

Response: colour
            Sum Sq  Df F value             Pr(>F)
tester      56.276  14  7.6546 0.000000000002169
storage      2.521   1  4.8003           0.02981
factor(age)  1.501   4  0.7147           0.58294
order        1.504   1  2.8643           0.09239
Residuals   89.799 171
```

```
> fit.col4 <- update(fit.col3, .~. - factor(age))
> Anova(fit.col4, type="II")
Anova Table (Type II tests)

Response: colour
          Sum Sq  Df F value            Pr(>F)
tester    55.675  14  7.6225 0.000000000002111
storage    2.521   1  4.8318           0.02925
order      1.504   1  2.8831           0.09129
Residuals 91.300 175

> fit.col5 <- update(fit.col4, .~. - order)
> Anova(fit.col5, type="II")
Anova Table (Type II tests)

Response: colour
          Sum Sq  Df F value            Pr(>F)
tester    55.675  14  7.5418 0.000000000002784
storage    2.521   1  4.7807            0.0301
Residuals 92.804 176

> summary(fit.col5)

Call:
lm(formula = colour ~ tester + storage, data = Sensory)

Residuals:
    Min      1Q  Median      3Q     Max
-2.6146 -0.4854  0.1354  0.3698  2.1146

Coefficients:
              Estimate Std. Error t value     Pr(>|t|)
(Intercept)     4.7146     0.1706  27.632      < 2e-16
tester2         0.3500     0.2296   1.524     0.129255
tester3         0.1500     0.2296   0.653     0.514463
tester4        -0.7250     0.3038  -2.387     0.018063
tester5        -0.2250     0.2436  -0.924     0.356854
tester6        -1.6000     0.2651  -6.034 0.0000000092
tester7         0.4000     0.2651   1.509     0.133204
tester8        -0.9000     0.2296  -3.919     0.000127
tester10       -0.1000     0.2436  -0.411     0.681881
tester11        0.1500     0.2436   0.616     0.538777
tester12       -0.2250     0.3038  -0.741     0.459869
tester13       -0.3500     0.3977  -0.880     0.380062
tester14       -0.8500     0.3038  -2.798     0.005712
tester15        0.0250     0.3038   0.082     0.934503
tester16       -0.6000     0.3977  -1.509     0.133204
storagestored  -0.2292     0.1048  -2.186     0.030100

Residual standard error: 0.7262 on 176 degrees of freedom
Multiple R-squared: 0.3854,      Adjusted R-squared: 0.333
F-statistic: 7.358 on 15 and 176 DF,  p-value: 0.000000000001743

> par(mfrow=c(2,2))
> plot(fit.col4, which=c(1,3,5))
> qq.plot(resid(fit.col5),col="black")
> ## Some kinks and some points fall below the bounds at
> ## the lower end. Not too dramatic and shouldn't cause any problems.
> ## Especially since we're dealing with data limited to the [1,5] interval rather
> ## than normally distributed data.

> ## Now obtain the means for each factor
> mt.col.m <- model.tables(aov(colour ~ tester + storage, data=Sensory),
+                           type="mean")
> summary(predict(fit.col4)) ## Check the fit - don't want too many above 5
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  2.767   3.993   4.521   4.375   4.757   5.183
> round(mt.col.m$tables[[3]],1)
storage
fresh cut    stored
      4.5       4.3
```

```
> ## Smell
> ## ==========
> win.metafile(file="../graphics/smell_hist.wmf", width=plot.width2,
+              height=plot.height2)
> print(histogram(~smell | session + storage, data=Sensory, as.table=TRUE,
+                 breaks=(0:5+0.5), type="count", ylim=c(0,15),
+                 xlab="Smell Score", ylab="Number of responses",
+                 scales=list(alternating=FALSE),
+                 panel=function(x,...){
+                   smy <- summary(x)
+                   panel.grid(-1,-1)
+                   panel.histogram(x,...)
+                   panel.text(0.5,14,paste("Median =",smy[3]),adj=0,cex=0.7)
+                   panel.text(0.5,12.5,paste("Mean =",smy[4]),adj=0,cex=0.7)
+                   panel.text(0.5,11,paste("St Dev =",round(sd(x),2)),adj=0,cex=0.7)
+                 },
+                 strip=strip.custom(strip.levels=c(TRUE,TRUE),
+                   par.strip.text=list(cex=0.9))
+                 ))
> dev.off()
windows
      2

> ## Fit a model which takes into account a different baseline per panellist
> ## (tester). Allows for a difference between storage duration and the order of
> ## tasting (and their interaction), and finally allows for different aged meat
> ## (different animals) to have different average scores.
> fit.smell1 <- lm(smell ~ tester + storage*factor(age) + storage*order, data=Sensory)
> Anova(fit.smell1, type="II")
Anova Table (Type II tests)

Response: smell
                     Sum Sq  Df F value         Pr(>F)
tester               63.402  14  5.7465 0.000000004672
storage               8.755   1 11.1095       0.001059
factor(age)           2.583   4  0.8195       0.514389
order                 1.139   1  1.4454       0.230985
storage:factor(age)   3.683   4  1.1682       0.326727
storage:order         1.625   1  2.0623       0.152863
Residuals           130.821 166

> par(mfrow=c(2,2))
> plot(fit.smell1, which=c(1,3,5))
> qq.plot(resid(fit.smell1),col="black")

> fit.smell2 <- update(fit.smell1, .~. - storage:factor(age))
> Anova(fit.smell2, type="II")
Anova Table (Type II tests)

Response: smell
               Sum Sq  Df F value         Pr(>F)
tester         63.402  14  5.7239 0.000000004662
storage         8.755   1 11.0657       0.001078
factor(age)     2.583   4  0.8163       0.516380
order           1.584   1  2.0025       0.158869
storage:order   1.623   1  2.0518       0.153866
Residuals     134.504 170

> fit.smell3 <- update(fit.smell2, .~. - factor(age))
> Anova(fit.smell3, type="II")
Anova Table (Type II tests)

Response: smell
               Sum Sq  Df F value         Pr(>F)
tester         63.471  14  5.7544 0.000000003758
storage         8.755   1 11.1127       0.001048
order           1.584   1  2.0110       0.157952
storage:order   0.915   1  1.1611       0.282735
Residuals     137.087 174
```

```
> fit.smell4 <- update(fit.smell3, .~. - storage:order)
> Anova(fit.smell4, type="II")
Anova Table (Type II tests)

Response: smell
           Sum Sq  Df F value         Pr(>F)
tester     64.236  14  5.8184 0.000000002826
storage     8.755   1 11.1025       0.001052
order       1.584   1  2.0091       0.158132
Residuals 138.002 175

> fit.smell5 <- update(fit.smell4, .~. - order)
> Anova(fit.smell5, type="II")
Anova Table (Type II tests)

Response: smell
           Sum Sq  Df F value         Pr(>F)
tester     64.236  14  5.7853 0.000000003166
storage     8.755   1 11.0392       0.001085
Residuals 139.586 176

> summary(fit.smell5)

Call:
lm(formula = smell ~ tester + storage, data = Sensory)

Residuals:
    Min      1Q  Median      3Q     Max
-3.2865 -0.4818  0.2031  0.6177  1.6135

Coefficients:
              Estimate Std. Error t value   Pr(>|t|)
(Intercept)     4.6635     0.2092  22.287    < 2e-16
tester2         0.2000     0.2816   0.710   0.478536
tester3         0.0500     0.2816   0.178   0.859286
tester4        -1.3250     0.3725  -3.557   0.000483
tester5        -0.5125     0.2987  -1.716   0.087969
tester6        -0.7000     0.3252  -2.153   0.032712
tester7         0.1333     0.3252   0.410   0.682291
tester8        -0.8500     0.2816  -3.018   0.002920
tester10       -0.0750     0.2987  -0.251   0.802042
tester11       -0.0125     0.2987  -0.042   0.966668
tester12       -0.5750     0.3725  -1.543   0.124526
tester13       -1.2000     0.4878  -2.460   0.014855
tester14       -1.8250     0.3725  -4.899 0.00000218
tester15       -0.8250     0.3725  -2.214   0.028081
tester16       -1.9500     0.4878  -3.998 0.00009398
storagestored  -0.4271     0.1285  -3.323   0.001085

Residual standard error: 0.8906 on 176 degrees of freedom
Multiple R-squared: 0.3434,      Adjusted R-squared: 0.2874
F-statistic: 6.136 on 15 and 176 DF,  p-value: 0.0000000002850

> par(mfrow=c(2,2))
> plot(fit.smell5, which=c(1,3,5))
> qq.plot(resid(fit.smell5),col="black")
> ## Some kinks and some points fall below the bounds at
> ## the lower end. Not too dramatic and shouldn't cause any problems.
> ## Especially since we're dealing with data limited to the [1,5] interval rather
> ## than normally distributed data.

> ## Now obtain the means for each factor
> mt.smell.m <- model.tables(aov(smell ~ tester + storage, data=Sensory),
+                          type="mean")
> summary(predict(fit.smell5)) ## Check the fit - don't want too many above 5
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  2.286   3.708   4.193   4.047   4.589   4.864
> round(mt.smell.m$tables[[3]],1)
storage
fresh cut    stored
      4.3       3.8
```

```
> ## Taste
> ## ==========
> win.metafile(file="../graphics/taste_hist.wmf", width=plot.width2,
+              height=plot.height2)
> print(histogram(~taste | session + storage, data=Sensory, as.table=TRUE,
+                 breaks=(0:5+0.5), type="count", ylim=c(0,15),
+                 xlab="Taste Score", ylab="Number of responses",
+                 scales=list(alternating=FALSE),
+                 panel=function(x,...){
+                   smy <- summary(x)
+                   panel.grid(-1,-1)
+                   panel.histogram(x,...)
+                   panel.text(0.5,14,paste("Median =",smy[3]),adj=0,cex=0.7)
+                   panel.text(0.5,12.5,paste("Mean =",smy[4]),adj=0,cex=0.7)
+                   panel.text(0.5,11,paste("St Dev =",round(sd(x),2)),adj=0,cex=0.7)
+                 },
+                 strip=strip.custom(strip.levels=c(TRUE,TRUE),
+                   par.strip.text=list(cex=0.9))
+                 ))
> dev.off()
windows
      2

> ## Fit a model which takes into account a different baseline per panellist
> ## (tester). Allows for a difference between storage duration and the order of
> ## tasting (and their interaction), and finally allows for different aged meat
> ## (different animals) to have different average scores.
> fit.taste1 <- lm(taste ~ tester + storage*factor(age) + storage*order, data=Sensory)
> Anova(fit.taste1, type="II")
Anova Table (Type II tests)

Response: taste
                     Sum Sq  Df F value     Pr(>F)
tester               53.675  14  3.8442 0.00001209
storage              12.027   1 12.0595   0.000658
factor(age)           5.888   4  1.4759   0.211774
order                 0.105   1  0.1057   0.745542
storage:factor(age)   2.716   4  0.6808   0.606199
storage:order         0.831   1  0.8328   0.362787
Residuals           164.560 165

> par(mfrow=c(2,2))
> plot(fit.taste1, which=c(1,3,5))
> qq.plot(resid(fit.taste1),col="black")

> fit.taste2 <- update(fit.taste1, .~. - storage:factor(age))
> Anova(fit.taste2, type="II")
Anova Table (Type II tests)

Response: taste
               Sum Sq  Df F value     Pr(>F)
tester         53.680  14  3.8738 0.00001024
storage        12.027   1 12.1513   0.000625
factor(age)     5.888   4  1.4872   0.208232
order           0.076   1  0.0771   0.781588
storage:order   0.854   1  0.8626   0.354324
Residuals     167.276 169

> fit.taste3 <- update(fit.taste2, .~. - storage:order)
> Anova(fit.taste3, type="II")
Anova Table (Type II tests)

Response: taste
             Sum Sq  Df F value      Pr(>F)
tester       53.685  14  3.8773 0.000009985
storage      12.027   1 12.1612   0.0006211
factor(age)   6.073   4  1.5353   0.1941281
order         0.076   1  0.0772   0.7814998
Residuals   168.130 170
```

```
> fit.taste4 <- update(fit.taste3, .~. - order)
> Anova(fit.taste4, type="II")
Anova Table (Type II tests)

Response: taste
             Sum Sq  Df F value     Pr(>F)
tester       53.691  14  3.8988 0.00000903
storage      12.012   1 12.2120  0.0006047
factor(age)   6.072   4  1.5432  0.1918542
Residuals   168.206 171

> fit.taste5 <- update(fit.taste4, .~. - factor(age))
> Anova(fit.taste5, type="II")
Anova Table (Type II tests)

Response: taste
           Sum Sq  Df F value     Pr(>F)
tester     52.937  14  3.7969 0.00001334
storage    12.000   1 12.0498  0.0006525
Residuals 174.278 175

> summary(fit.taste5)

Call:
lm(formula = taste ~ tester + storage, data = Sensory)

Residuals:
    Min      1Q  Median      3Q     Max
-2.6674 -0.5625  0.1493  0.6422  2.5007

Coefficients:
              Estimate Std. Error t value   Pr(>|t|)
(Intercept)     5.0007     0.2345  21.321    < 2e-16
tester2        -0.1000     0.3156  -0.317   0.751711
tester3        -0.8500     0.3156  -2.693   0.007759
tester4        -2.0000     0.4175  -4.791 0.00000353
tester5        -0.3750     0.3347  -1.120   0.264101
tester6        -1.1667     0.3644  -3.202   0.001623
tester7        -0.3333     0.3644  -0.915   0.361576
tester8        -1.1500     0.3156  -3.644   0.000353
tester10       -0.3750     0.3347  -1.120   0.264101
tester11       -0.8125     0.3347  -2.427   0.016220
tester12       -0.6430     0.4384  -1.467   0.144248
tester13       -1.2500     0.5466  -2.287   0.023399
tester14       -1.6250     0.4175  -3.893   0.000141
tester15       -0.3750     0.4175  -0.898   0.370272
tester16       -1.2500     0.5466  -2.287   0.023399
storagestored  -0.5015     0.1445  -3.471   0.000652

Residual standard error: 0.9979 on 175 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared: 0.2716,      Adjusted R-squared: 0.2091
F-statistic: 4.349 on 15 and 175 DF,  p-value: 0.0000006919

> par(mfrow=c(2,2))
> plot(fit.taste5, which=c(1,3,5))
> qq.plot(resid(fit.taste5),col="black")
> ## Some kinks and some points fall below the bounds at
> ## the lower end. Not too dramatic and shouldn't cause any problems.
> ## Especially since we're dealing with data limited to the [1,5] interval rather
> ## than normally distributed data.

> ## Now obtain the means for each factor
> mt.taste.m <- model.tables(aov(taste ~ tester + storage, data=Sensory),
+                          type="mean")
> summary(predict(fit.taste5)) ## Check the fit - don't want too many above 5
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  2.499   3.687   4.124   4.063   4.499   5.001
> round(mt.taste.m$tables[[3]],1)
storage
fresh cut    stored
      4.3       3.8
```

```
> ## Texture
> ## ==========
> win.metafile(file="../graphics/texture_hist.wmf", width=plot.width2,
+              height=plot.height2)
> print(histogram(~texture | session + storage, data=Sensory, as.table=TRUE,
+                 breaks=(0:5+0.5), type="count", ylim=c(0,15),
+                 xlab="Texture Score", ylab="Number of responses",
+                 scales=list(alternating=FALSE),
+                 panel=function(x,...){
+                   smy <- summary(x)
+                   panel.grid(-1,-1)
+                   panel.histogram(x,...)
+                   panel.text(0.5,14,paste("Median =",smy[3]),adj=0,cex=0.7)
+                   panel.text(0.5,12.5,paste("Mean =",smy[4]),adj=0,cex=0.7)
+                   panel.text(0.5,11,paste("St Dev =",round(sd(x),2)),adj=0,cex=0.7)
+                 },
+                 strip=strip.custom(strip.levels=c(TRUE,TRUE),
+                   par.strip.text=list(cex=0.9))
+                 ))
> dev.off()
windows
      2

> ## Fit a model which takes into account a different baseline per panellist
> ## (tester). Allows for a difference between storage duration and the order of
> ## tasting (and their interaction), and finally allows for different aged meat
> ## (different animals) to have different average scores.
> fit.texture1 <- lm(texture ~ tester + storage*factor(age) + storage*order,
data=Sensory)
> Anova(fit.texture1, type="II")
Anova Table (Type II tests)

Response: texture
                     Sum Sq  Df F value        Pr(>F)
tester               64.964  14  5.0231 0.00000009102
storage               8.847   1  9.5768      0.002315
factor(age)           4.353   4  1.1781      0.322372
order                 0.013   1  0.0144      0.904654
storage:factor(age)   4.600   4  1.2450      0.293937
storage:order         0.152   1  0.1648      0.685338
Residuals           152.425 165

> par(mfrow=c(2,2))
> plot(fit.texture1, which=c(1,3,5))
> qq.plot(resid(fit.texture1),col="black")

> fit.texture2 <- update(fit.texture1, .~. - storage:order)
> Anova(fit.texture2, type="II")
Anova Table (Type II tests)

Response: texture
                     Sum Sq  Df F value        Pr(>F)
tester               64.975  14  5.0494 0.00000008019
storage               8.847   1  9.6252      0.002256
factor(age)           4.073   4  1.1079      0.354596
order                 0.013   1  0.0145      0.904414
storage:factor(age)   4.782   4  1.3006      0.271948
Residuals           152.577 166

> fit.texture3 <- update(fit.texture2, .~. - order)
> Anova(fit.texture3, type="II")
Anova Table (Type II tests)

Response: texture
                     Sum Sq  Df F value        Pr(>F)
tester               64.971  14  5.0790 0.00000006965
storage               8.907   1  9.7481      0.002116
factor(age)           4.027   4  1.1017      0.357539
storage:factor(age)   6.254   4  1.7112      0.149811
Residuals           152.591 167
```

```
> fit.texture4 <- update(fit.texture3, .~. - storage:factor(age))
> Anova(fit.texture4, type="II")
Anova Table (Type II tests)

Response: texture
             Sum Sq  Df F value        Pr(>F)
tester       64.700  14  4.9751 0.00000009964
storage       8.907   1  9.5886      0.002289
factor(age)   4.027   4  1.0837      0.366210
Residuals   158.845 171

> fit.texture5 <- update(fit.texture4, .~. - factor(age))
> Anova(fit.texture5, type="II")
Anova Table (Type II tests)

Response: texture
           Sum Sq  Df F value        Pr(>F)
tester     66.238  14  5.0836 0.00000005915
storage     8.993   1  9.6624      0.002196
Residuals 162.872 175

> summary(fit.texture5)

Call:
lm(formula = texture ~ tester + storage, data = Sensory)

Residuals:
     Min       1Q   Median       3Q      Max
-2.98293 -0.46707  0.03293  0.58293  1.96707

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)     4.4671     0.2267  19.701  < 2e-16
tester2         0.5000     0.3051   1.639 0.103020
tester3        -0.0500     0.3051  -0.164 0.870003
tester4        -1.0000     0.4036  -2.478 0.014166
tester5        -0.1875     0.3236  -0.579 0.563026
tester6        -1.2500     0.3523  -3.548 0.000498
tester7         0.7500     0.3523   2.129 0.034648
tester8        -0.9500     0.3051  -3.114 0.002157
tester10       -0.1250     0.3236  -0.386 0.699740
tester11        0.1875     0.3236   0.579 0.563026
tester12        0.2904     0.4238   0.685 0.494059
tester13       -0.2500     0.5284  -0.473 0.636714
tester14       -1.0000     0.4036  -2.478 0.014166
tester15        0.6250     0.4036   1.549 0.123269
tester16       -0.5000     0.5284  -0.946 0.345326
storagestored  -0.4341     0.1397  -3.108 0.002196

Residual standard error: 0.9647 on 175 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared: 0.3165,      Adjusted R-squared: 0.258
F-statistic: 5.403 on 15 and 175 DF,  p-value: 0.000000006788

> par(mfrow=c(2,2))
> plot(fit.texture5, which=c(1,3,5))
> qq.plot(resid(fit.texture5),col="black")
> ## Some kinks and some points fall below the bounds at
> ## the lower end. Not too dramatic and shouldn't cause any problems.
> ## Especially since we're dealing with data limited to the [1,5] interval rather
> ## than normally distributed data.

> ## Now obtain the means for each factor
> mt.texture.m <- model.tables(aov(texture ~ tester + storage, data=Sensory),
+                          type="mean")
> summary(predict(fit.texture5)) ## Check the fit - don't want too many above 5
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  2.783   3.525   4.220   4.094   4.533   5.217
> round(mt.texture.m$tables[[3]],1)
storage
fresh cut    stored
      4.3       3.9
```

```
> ## Overall
> ## ==========
> win.metafile(file="../graphics/overall_hist.wmf", width=plot.width2,
+              height=plot.height2)
> print(histogram(~overall | session + storage, data=Sensory, as.table=TRUE,
+                 breaks=(0:5+0.5), type="count", ylim=c(0,15),
+                 xlab="Overall Score", ylab="Number of responses",
+                 scales=list(alternating=FALSE),
+                 panel=function(x,...){
+                   smy <- summary(x)
+                   panel.grid(-1,-1)
+                   panel.histogram(x,...)
+                   panel.text(0.5,14,paste("Median =",smy[3]),adj=0,cex=0.7)
+                   panel.text(0.5,12.5,paste("Mean =",smy[4]),adj=0,cex=0.7)
+                   panel.text(0.5,11,paste("St Dev =",round(sd(x),2)),adj=0,cex=0.7)
+                 },
+                 strip=strip.custom(strip.levels=c(TRUE,TRUE),
+                   par.strip.text=list(cex=0.9))
+                 ))
> dev.off()
windows
      2

> ## Fit a model which takes into account a different baseline per panellist
> ## (tester). Allows for a difference between storage duration and the order of
> ## tasting (and their interaction), and finally allows for different aged meat
> ## (different animals) to have different average scores.
> fit.overall1 <- lm(overall ~ tester + storage*factor(age) + storage*order,
data=Sensory)
> Anova(fit.overall1, type="II")
Anova Table (Type II tests)

Response: overall
                     Sum Sq  Df F value     Pr(>F)
tester               44.253  14  3.7602 0.00001715
storage              12.462   1 14.8246  0.0001685
factor(age)           4.186   4  1.2448  0.2940042
order                 0.354   1  0.4209  0.5173833
storage:factor(age)   1.520   4  0.4521  0.7707302
storage:order         1.282   1  1.5253  0.2185781
Residuals           138.705 165

> par(mfrow=c(2,2))
> plot(fit.overall1, which=c(1,3,5))
> qq.plot(resid(fit.overall1),col="black")

> fit.overall2 <- update(fit.overall1, .~. - storage:factor(age))
> Anova(fit.overall2, type="II")
Anova Table (Type II tests)

Response: overall
               Sum Sq  Df F value     Pr(>F)
tester         44.257  14  3.8099 0.00001339
storage        12.462   1 15.0194  0.0001520
factor(age)     4.186   4  1.2612  0.2872774
order           0.238   1  0.2868  0.5929890
storage:order   1.355   1  1.6327  0.2030882
Residuals     140.226 169

> fit.overall3 <- update(fit.overall2, .~. - factor(age))
> Anova(fit.overall3, type="II")
Anova Table (Type II tests)

Response: overall
               Sum Sq  Df F value     Pr(>F)
tester         43.690  14  3.7385 0.00001738
storage        12.461   1 14.9275  0.0001578
order           0.237   1  0.2845  0.5944431
storage:order   1.263   1  1.5124  0.2204360
Residuals     144.411 173
```

```
> fit.overall4 <- update(fit.overall3, .~. - storage:order)
> Anova(fit.overall4, type="II")
Anova Table (Type II tests)

Response: overall
           Sum Sq  Df F value     Pr(>F)
tester     43.363  14  3.6997 0.00002028
storage    12.461   1 14.8837  0.0001609
order       0.237   1  0.2837  0.5949805
Residuals 145.674 174

> fit.overall5 <- update(fit.overall4, .~. - order)
> Anova(fit.overall5, type="II")
Anova Table (Type II tests)

Response: overall
           Sum Sq  Df F value     Pr(>F)
tester     43.380  14  3.7163 0.00001874
storage    12.434   1 14.9126  0.0001583
Residuals 145.911 175

> summary(fit.overall5)

Call:
lm(formula = overall ~ tester + storage, data = Sensory)

Residuals:
    Min      1Q  Median      3Q     Max
-2.7948 -0.5052  0.1614  0.6052  2.0052

Coefficients:
              Estimate Std. Error t value  Pr(>|t|)
(Intercept)    4.90524    0.21461  22.856   < 2e-16
tester2       -0.15000    0.28875  -0.519  0.604085
tester3       -0.60000    0.28875  -2.078  0.039178
tester4       -1.40000    0.38198  -3.665  0.000328
tester5       -0.40000    0.30627  -1.306  0.193251
tester6       -1.40000    0.33342  -4.199 0.0000426
tester7       -0.06667    0.33342  -0.200  0.841755
tester8       -1.15000    0.28875  -3.983 0.0000998
tester10      -0.46250    0.30627  -1.510  0.132818
tester11      -0.21250    0.30627  -0.694  0.488705
tester12      -0.40075    0.40111  -0.999  0.319127
tester13      -1.15000    0.50013  -2.299  0.022664
tester14      -1.27500    0.38198  -3.338  0.001031
tester15      -0.40000    0.38198  -1.047  0.296467
tester16      -1.15000    0.50013  -2.299  0.022664
storagestored -0.51048    0.13219  -3.862  0.000158

Residual standard error: 0.9131 on 175 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared: 0.277, Adjusted R-squared: 0.2151
F-statistic:  4.47 on 15 and 175 DF,  p-value: 0.0000004046

> par(mfrow=c(2,2))
> plot(fit.overall5, which=c(1,3,5))
> qq.plot(resid(fit.overall5),col="black")
> ## Looks good.

> ## Now obtain the means for each factor
> mt.overall.m <- model.tables(aov(overall ~ tester + storage, data=Sensory),
+                          type="mean")
> summary(predict(fit.overall4)) ## Check the fit - don't want too many above 5
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  2.947   3.740   4.197   4.079   4.486   4.953
> round(mt.overall.m$tables[[3]],1)
storage
fresh cut    stored
      4.3       3.8
```

```
> ## ----------------------------------------------------------------------
> ## Combine micro of slices with sensory
> ## ----------------------------------------------------------------------
> tmp1 <- with(Micro.slices,
+              data.frame(sample=factor(rep(levels(sample), each=5),
+                           levels=levels(sample)),
+                         session=factor(rep(1:5, times=4)),
+                         storage=factor(rep(c("stored", "fresh cut"), each=10)),
+                         apc=c(tapply(log10(apc), list(session, sample),
+                           mean, na.rm=TRUE)),
+                         lab=c(tapply(log10(lab), list(session, sample),
+                           mean, na.rm=TRUE)) ))
> tmp2 <- with(Sensory,
+              data.frame(appearance=c(tapply(appearance, list(session, sample),
+                           mean, na.rm=TRUE)),
+                         colour=c(tapply(colour, list(session, sample),
+                           mean, na.rm=TRUE)),
+                         smell=c(tapply(smell, list(session, sample),
+                           mean, na.rm=TRUE)),
+                         taste=c(tapply(taste, list(session, sample),
+                           mean, na.rm=TRUE)),
+                         texture=c(tapply(texture, list(session, sample),
+                           mean, na.rm=TRUE)),
+                         overall=c(tapply(overall, list(session, sample),
+                           mean, na.rm=TRUE)) ))
> SM <- cbind(tmp1,tmp2)

> win.metafile(file="../graphics/sensory_apc.wmf", width=plot.width2,
+              height=plot.height2)
> print(xyplot(appearance+colour+smell+taste+texture+overall ~ apc,
+              group=storage, data=SM,
+              ylab="Mean Score", pch=c(18,3), col=c(3,2),
+              xlab=expression(paste("log"[10]," APC (cfu/g)")),
+              scales=list(alternating=FALSE),
+              layout=c(2,3), as.table=TRUE))
> dev.off()
windows
      2

> ## Relate micro to the sensory observations.  Note that APC is now on the log10
> ## scale.
>
> ## Nothing is significant
> Anova(lm(appearance ~ apc*storage, data=SM), type="II")
Anova Table (Type II tests)

Response: appearance
             Sum Sq Df F value Pr(>F)
apc         0.01158  1  0.1639 0.6910
storage     0.21643  1  3.0638 0.0992
apc:storage 0.00033  1  0.0046 0.9468
Residuals   1.13022 16

> Anova(lm(appearance ~ apc+storage, data=SM), type="II")
Anova Table (Type II tests)

Response: appearance
           Sum Sq Df F value  Pr(>F)
apc       0.01158  1  0.1741 0.68175
storage   0.21643  1  3.2544 0.08898
Residuals 1.13055 17

> ## Only storage is significant, which we know from before.
> Anova(lm(colour ~ apc*storage, data=SM), type="II")
Anova Table (Type II tests)

Response: colour
             Sum Sq Df F value Pr(>F)
apc         0.00062  1  0.0130 0.9106
storage     0.24064  1  5.0667 0.0388
apc:storage 0.00871  1  0.1835 0.6741
Residuals   0.75992 16
```

```
> Anova(lm(colour ~ apc+storage, data=SM), type="II")
Anova Table (Type II tests)

Response: colour
           Sum Sq Df F value  Pr(>F)
apc       0.00062  1  0.0137 0.90829
storage   0.24064  1  5.3224 0.03391
Residuals 0.76863 17

> ## Only storage is significant, which we know from before.
> Anova(lm(smell ~ apc*storage, data=SM), type="II")
Anova Table (Type II tests)

Response: smell
             Sum Sq Df F value  Pr(>F)
apc         0.08116  1  1.1290 0.30376
storage     0.58470  1  8.1338 0.01153
apc:storage 0.13225  1  1.8397 0.19381
Residuals   1.15015 16

> Anova(lm(smell ~ apc+storage, data=SM), type="II")
Anova Table (Type II tests)

Response: smell
           Sum Sq Df F value  Pr(>F)
apc       0.08116  1  1.0759 0.31415
storage   0.58470  1  7.7510 0.01273
Residuals 1.28240 17

> ## Only storage is significant, which we know from before.
> Anova(lm(taste ~ apc*storage, data=SM), type="II")
Anova Table (Type II tests)

Response: taste
             Sum Sq Df F value   Pr(>F)
apc         0.10863  1  0.9684 0.339739
storage     1.28774  1 11.4793 0.003753
apc:storage 0.07964  1  0.7099 0.411890
Residuals   1.79486 16

> Anova(lm(taste ~ apc+storage, data=SM), type="II")
Anova Table (Type II tests)

Response: taste
           Sum Sq Df F value   Pr(>F)
apc       0.10863  1  0.9852 0.334846
storage   1.28774  1 11.6786 0.003282
Residuals 1.87450 17

> ## Storage is significant and APC is marginally significant.
> Anova(lm(texture ~ apc*storage, data=SM), type="II")
Anova Table (Type II tests)

Response: texture
             Sum Sq Df F value   Pr(>F)
apc         0.35699  1  4.3232 0.054038
storage     1.22883  1 14.8814 0.001393
apc:storage 0.02244  1  0.2717 0.609302
Residuals   1.32120 16

> Anova(lm(texture ~ apc+storage, data=SM), type="II")
Anova Table (Type II tests)

Response: texture
           Sum Sq Df F value   Pr(>F)
apc       0.35699  1  4.5167 0.048524
storage   1.22883  1 15.5474 0.001049
Residuals 1.34364 17
```

```
> summary(lm(texture ~ apc+storage, data=SM))

Call:
lm(formula = texture ~ apc + storage, data = SM)

Residuals:
     Min       1Q   Median       3Q      Max
-0.50146 -0.12414  0.02377  0.15970  0.57018

Coefficients:
              Estimate Std. Error t value         Pr(>|t|)
(Intercept)    3.88139    0.21933  17.697 0.00000000000219
apc            0.07789    0.03665   2.125          0.04852
storagestored -0.52911    0.13419  -3.943          0.00105

Residual standard error: 0.2811 on 17 degrees of freedom
Multiple R-squared: 0.4877,      Adjusted R-squared: 0.4274
F-statistic: 8.092 on 2 and 17 DF,  p-value: 0.003396

> ## Only storage is significant, which we know from before.
> Anova(lm(overall ~ apc*storage, data=SM), type="II")
Anova Table (Type II tests)

Response: overall
             Sum Sq Df F value   Pr(>F)
apc         0.06193  1  0.7660 0.394407
storage     1.30166  1 16.1008 0.001005
apc:storage 0.01651  1  0.2042 0.657387
Residuals   1.29351 16

> Anova(lm(overall ~ apc+storage, data=SM), type="II")
Anova Table (Type II tests)

Response: overall
           Sum Sq Df F value    Pr(>F)
apc       0.06193  1  0.8036 0.3825345
storage   1.30166  1 16.8915 0.0007309
Residuals 1.31002 17

> win.metafile(file="../graphics/sensory_lab.wmf", width=plot.width2,
+              height=plot.height2)
> print(xyplot(appearance+colour+smell+taste+texture+overall ~ lab,
+              group=storage, data=SM,
+              ylab="Mean Score", pch=c(18,3), col=c(3,2),
+              xlab=expression(paste("log"[10]," APC (cfu/g)")),
+              scales=list(alternating=FALSE),
+              layout=c(2,3), as.table=TRUE))
> dev.off()
windows
      2

> ## Relate micro to the sensory observations.  Note that LAB is now on the log10
> ## scale.

> ## Nothing is significant
> Anova(lm(appearance ~ lab*storage, data=SM), type="II")
Anova Table (Type II tests)

Response: appearance
             Sum Sq Df F value  Pr(>F)
lab         0.00625  1  0.0881 0.77046
storage     0.23760  1  3.3484 0.08597
lab:storage 0.00052  1  0.0074 0.93269
Residuals   1.13535 16

> Anova(lm(appearance ~ lab+storage, data=SM), type="II")
Anova Table (Type II tests)

Response: appearance
           Sum Sq Df F value  Pr(>F)
lab       0.00625  1  0.0935 0.76345
storage   0.23760  1  3.5560 0.07654
Residuals 1.13588 17
```

```
> ## Only storage is significant, which we know from before.
> Anova(lm(colour ~ lab*storage, data=SM), type="II")
Anova Table (Type II tests)

Response: colour
             Sum Sq Df F value Pr(>F)
lab         0.00179  1  0.0379 0.8481
storage     0.25294  1  5.3469 0.0344
lab:storage 0.01056  1  0.2232 0.6430
Residuals   0.75690 16

> Anova(lm(colour ~ lab+storage, data=SM), type="II")
Anova Table (Type II tests)

Response: colour
           Sum Sq Df F value  Pr(>F)
lab       0.00179  1  0.0397 0.84440
storage   0.25294  1  5.6029 0.03006
Residuals 0.76746 17

> ## Only storage is significant, which we know from before.
> Anova(lm(smell ~ lab*storage, data=SM), type="II")
Anova Table (Type II tests)

Response: smell
             Sum Sq Df F value  Pr(>F)
lab         0.08597  1  1.1678 0.29587
storage     0.62425  1  8.4799 0.01018
lab:storage 0.09974  1  1.3549 0.26148
Residuals   1.17785 16

> Anova(lm(smell ~ lab+storage, data=SM), type="II")
Anova Table (Type II tests)

Response: smell
           Sum Sq Df F value  Pr(>F)
lab       0.08597  1  1.1439 0.29977
storage   0.62425  1  8.3065 0.01035
Residuals 1.27759 17

> ## Only storage is significant, which we know from before.
> Anova(lm(taste ~ lab*storage, data=SM), type="II")
Anova Table (Type II tests)

Response: taste
             Sum Sq Df F value   Pr(>F)
lab         0.08803  1  0.7626 0.395439
storage     1.27003  1 11.0016 0.004362
lab:storage 0.04803  1  0.4161 0.528046
Residuals   1.84706 16

> Anova(lm(taste ~ lab+storage, data=SM), type="II")
Anova Table (Type II tests)

Response: taste
           Sum Sq Df F value   Pr(>F)
lab       0.08803  1  0.7897 0.386590
storage   1.27003  1 11.3929 0.003595
Residuals 1.89509 17

> ## Only storage is significant, which we know from before.
> Anova(lm(texture ~ lab*storage, data=SM), type="II")
Anova Table (Type II tests)

Response: texture
             Sum Sq Df F value   Pr(>F)
lab         0.29378  1  3.3884 0.084279
storage     1.16508  1 13.4376 0.002088
lab:storage 0.01960  1  0.2260 0.640922
Residuals   1.38725 16
```

```
> Anova(lm(texture ~ lab+storage, data=SM), type="II")
Anova Table (Type II tests)

Response: texture
           Sum Sq Df F value   Pr(>F)
lab       0.29378  1   3.550 0.076764
storage   1.16508  1  14.079 0.001588
Residuals 1.40684 17

> ## Only storage is significant, which we know from before.
> Anova(lm(overall ~ lab*storage, data=SM), type="II")
Anova Table (Type II tests)

Response: overall
             Sum Sq Df F value   Pr(>F)
lab         0.04353  1  0.5278 0.478012
storage     1.28865  1 15.6246 0.001140
lab:storage 0.00881  1  0.1068 0.748099
Residuals   1.31961 16

> Anova(lm(overall ~ lab+storage, data=SM), type="II")
Anova Table (Type II tests)

Response: overall
           Sum Sq Df F value    Pr(>F)
lab       0.04353  1  0.5571 0.4656238
storage   1.28865  1 16.4911 0.0008126
Residuals 1.32842 17
```