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Shelf-life evaluation of sliced lamb shoulders

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Abstract

A storage trial of sliced lamb shoulders was undertaken to assess microbiological and sensory attributes. The lamb utilised in this trial had previously been vaccuum packed, typical of product destined for the Japanese market. Lamb was sliced to a thickness of 4-5 mm, packed in overwrap trays and stored under refrigerated conditions for up to four days. Every day during the storage trial, the shoulders were tested for aerobic plate and lactic acid bacteria counts. Sensory evaluations were undertaken each day, using an untrained Japanese sensory panel. The results indicate that bacteria grew at a rate of about 0.42 $\log_{10}$ cfu/g per day on the sliced product. The microbiological flora on the sliced product consisted predominantly of lactic acid bacteria. Sensory scores for smell, taste, texture and overall impression decreased by about ½ a score over the storage trial. However, no relationship between microbiology and sensory score was found and despite the high bacteria levels; product after four days was still in good condition.

Executive Summary

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 for sale. The shelf-life for the overwrap trays is determined based on the Aerobic Plate Count (APC) using an incubation temperature of 35℃.of small surface pieces from the whole shoulders immediately prior to slicing. However, the microbiological flora of vacuum packed meat is expected to consist mainly of Lactic Acid Bacteria (LAB) which are unlikely to result in product spoilage, even at high levels.

The objective of this project was to undertake a storage trial of sliced lamb shoulders. The microbiological and organoleptic properties of sliced lamb shoulders were assessed and the relationship between microbiology and sensory attributes determined.

A total of 32 lamb shoulders, which had been vacuum packed for 13, 31, 34, and 35 days, were sliced and stored at 2℃ for up to four days. On each day, the sliced product was sampled for microbiological analysis and subjected to an untrained sensory panel consisting of 10 Japanese consumers living in Adelaide. The panel assessed the sliced product for appearance, colour, smell, taste, texture and overall impression. Microbiological tests consisted of APC and LAB under two incubation conditions: 25℃ for 96 hours and 35℃ for 48 hours.

As expected, LAB were the predominant bacterial group on the sliced product over the storage trial, irrespective of time. The microbial growth over the four days was 0.4-0.5 $\log_{10}$ cfu/g per day, which was consistent for APC and LAB at the different incubation temperatures. The length of time that whole lamb shoulders were vacuum packed had a significant effect on the starting levels of the sliced product – 13 day old lamb shoulders started with approximately 3 $\log_{10}$ cfu/g while 35 day old lamb shoulders were approximately 6 $\log_{10}$ cfu/g.

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). For appearance, colour, smell and taste, the sensory panel indicated that there were significant differences between the four different product ages. However, these differences were not consistent, which indicates that factors other than the age may have impacted on the sensory profile.

While appearance and colour scores were affected by the order of evaluation (last product scored on average 0.4 units lower than the first) they were unaffected by how long sliced product had been stored. The average scores for the first product evaluated were 4.1 and 4.4 for appearance and colour respectively.

In contrast, the remaining sensory attributes of the four different product ages were unaffected by the order in which were evaluated, but their score did reduce by an average 0.5 over the storage trial. The average scores on Day 1 were 4.1 for smell, 4.0 for taste, 4.1 for texture and 3.9 for the overall assessment.

Despite microbiological levels of sliced product from the young and old shoulders reaching over 5 and 7.5 $\log_{10}$ cfu/g after four days of storage, no relationship between microbiology and sensory attributes could be established.

Contents

1 Background

Several Australian sheep and lamb processors export vacuum packed lamb shoulders to Japan. There the lamb shoulders are sliced centrally, either mechanically (2-3 mm) or by hand (4-5 mm), packed in overwrap trays and distributed to various supermarket outlets.

Information from a Japanese supermarket chain indicates that microbiological testing of the vacuum-packed lamb shoulders is undertaken in the same way as fresh chicken and pork using Aerobic Plate Counts (APC) incubated at 35℃. The results of this testing then determine the shelf-life for the packed product. In particular, APC of $<10^3$ result in a shelf-life of three to four days, APC of 10^5 result in a shelf-life of two days, while product with APC $>10^8$ is unsaleable.

While these limits seem reasonable for fresh chicken or pork, it is believed that these are unreasonable for vacuum packed lamb, due to the difference in microbial ecology – vacuum packed meat contains mainly lactic acid bacteria, which are unlikely to result in product spoilage at these levels.

To assess this hypothesis, a shelf-life trial using various ages of vacuum packed lamb was undertaken. Lamb shoulders were sliced, packed and stored under conditions similar to those in Japan. The sliced product was then stored for up to four days and assessed daily for microbiology and organoleptic characteristics (appearance, smell and taste) by a panel of Japanese consumers.

2 Project Objectives

The project objective was to assess the microbiological and organoleptic properties of lamb shoulders which had been vacuum packed for different lengths of time, sliced, re-packed in overwrap trays and stored under commercial refrigeration conditions for up to four days.

3 Methodology

3.1 Raw Materials

The trial was conducted on 32 lamb shoulders (5055, foreshank removed – Handbook of Australian Meat, 7th Ed) packed into vacuum bags, two to a bag and stored for 13, 31, 34, and 35 days (four bags each) at between -1.5 and 0℃. The shoulders were collected from the processor at approximately 06:00 on 20 July 2009 and transported by air to Adelaide, arriving at 10:00. They were then taken by unrefrigerated transport to Regency TAFE. Temperature on arrival was 4.5℃ and they were stored in a coolroom (2℃) until further processing.

3.2 Slicing and Packaging

Slicing and packaging of product was undertaken on 20 July 2009 between 12:00 and 17:00. All processing was undertaken in a room chilled to 8℃. Each shoulder was opened aseptically on a clean and sanitised board. After opening, small surface pieces, totalling 25 g were removed for microbiological testing (see Section 3.4). A qualified butcher trimmed each shoulder and sliced them 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[1] to a pack weight of approximately 200-250 g. No vacuum packaging, MAP or heat sealing was used.

[1] As used in Japan – a roll of cling film was provided by MLA.

3.3 Storage

The packed shoulders were stored in a commercial coolroom at 2℃. They were moved the day prior to being used for sensory evaluation at approximately 16:30 and kept overnight in a commercial display cabinet under lights (2℃). On the day of the evaluation, the product was moved at 09:30 from the display cabinet to a domestic fridge (5℃) in the kitchen adjoining the sensory laboratory. Product was removed from the fridge 30 minutes before testing and placed on the kitchen bench.

3.4 Microbiological Testing

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

Slices were collected immediately after slicing and prior to sensory evaluation each day and divided into triplicate samples of 25 g each (referred to as **"slices"**). Slices collected prior to sensory evaluation were stored in a fridge (5℃) until the following day, when they were tested.

All meat samples were homogenised for 60 sec in 225 ml Peptone Saline Solution using a stomacher and serial dilutions prepared using 9 mL volumes of Peptone Saline Solution. The data are provided in Appendix 2: Microbiological data.

3.4.1 Aerobic Plate Count

Serial decimal dilutions were inoculated (1 mL) onto two sets of Petrifilm Aerobic Count Plates (3M Corp) with one set incubated at 25℃ ± 1℃ for 96 h ± 3 h and the other at 35℃ ± 1℃ for 48 h ± 3 h. After incubation, plates were examined as per the manufacturer's instructions and the aerobic plate count calculated for each incubation condition. The limit of detection was 10 cfu/g.

3.4.2 Lactic Acid Bacteria

Volumes of each decimal dilution (2 mL) were added to an equal volume of double-strength MRS broth (Oxoid Pty Ltd, Adelaide, Australia) and mixed thoroughly. An aliquot (1 mL) of the MRS suspension was inoculated onto each of two sets of Petrifilm Aerobic Count Plates (3M Corp) with one set incubated at 25℃ ± 1℃ for 96 h ± 3 h and the other at 35℃ ± 1℃ for 48 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.

3.5 Sensory Evaluation

Sensory testing was undertaken between 18:00 and 19:30 on 21 July 2009 (Day 1), 22 July (Day 2), 23 July (Day 3) and 24 July (Day 4) in the sensory laboratories at the Regency TAFE SA campus.

3.5.1 Sensory Panel

The panel consisted of 10 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
- Balance between male and females

The panel profile is provided in Appendix 1: Sensory Panel Profile. 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.

3.5.2 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.

3.5.3 Sensory Testing

Product age was randomised separately for each day before each evaluation as follows [R]ed = 13 days old, [G]reen = 31 days old, [Y]ellow = 34 days old, [B]lue = 35 days old:

- Day 1: Y, B, G, R
- Day 2: B, G, Y, R
- Day 3: B, Y, G, R
- Day 4: R, Y, B, G

Each age was identified by a coloured dot on the packaging (the age was unknown to panellists) and all sensory evaluations were completed for one age before moving onto the next age product. Each product was photographed on Days 2, 3, 4 (Appendix 4: Photographs) immediately prior to sensory evaluation.

Panellists were seated in individual booths (same booths for all days) and five packs of the product were individually presented to each of two panellists (in turn) for answering Questions 1 and 2.

For each set of two panellists, the product was then 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 then presented to the second panellist.

Finally, the product was cooked for approximately 45 seconds on each side using a stainless steel pan; pans were washed and dried between product ages. This was done by a fully qualified chef who trained at Tokyo Shokuryo Gakuin for a total of six months over several years. The product was served on individual plates and presented individually to each panellist for answering Questions 4-6.

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

3.6 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. That is, the time the shoulders had been vacuum packed for – takes values 13, 31, 34, or 35 days.
- **Day**: The number of days after slicing, prior to microbiological and sensory evaluation – 0, 1, 2, 3, and 4 days, where Day 0 indicates the day of slicing.
- **Hours**: The time in hours between sample collection/slicing and microbiological testing. For pieces this relates to the time between collection of pieces and testing (both on Day 0). For slices, this relates to the time of when all slicing was finished (17:00 on Day 0) and the time at which microbiological testing was carried out on the sample.
- **Type**: The type of samples used – “pieces” or “slices” (see Section 3.4)
- **Sample**: The sample replicate – all microbiological tests were undertaken in triplicate.
- **APC25**: The result of the Aerobic Plate Count obtained when incubating the sample at 25℃.
- **APC35**: The result of the Aerobic Plate Count obtained when incubating the sample at 35℃.
- **LAB25**: The result of the Lactic Acid Bacteria count obtained when incubating the sample at 25℃.
- **LAB35**: The result of the Lactic Acid Bacteria count obtained when incubating the sample at 35℃.

Ten microbiological results were observed below the limit of detection. In these cases, the limit of detection was substituted for the actual value to allow the calculation of the $\log_{10}$ and subsequently, the mean. It is recognised that this approach will slightly bias the mean upwards (higher than the true mean) but due to the small number of these values is likely to have little practical impact.

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

- **Age**: As for microbiological data (not identified to panellists).
- **Day:** As for microbiological data.
- **Order**: The order in which product was tasted on any one day – given by values 1 to 4.
- **Dot**: The colour of dot used to identify product of different ages.
- **Booth**: The booth the assessment was made in; this relates directly to the person who made the assessment as people were required to sit in the same booth on each evaluation day.
- **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).

All graphics and statistical models were produced using the R software version 2.9.1 (R Development Core Team 2009).

An analysis of variance was used to assess whether there were significant differences between the results obtained for **Type="pieces"** versus those obtained for **Type="slices"** (for slices sampled immediately after slicing only). The model fitted to **APC25** consisted of an overall mean, the **age** and **type** effects and their interaction. It was of the following form, with **models** for **APC35**, **LAB25** and **LAB35** taking similar forms:

log10(APC25) = mean + type + age + type:age

In addition, linear models were fitted to the microbiological results to estimate their growth over time. These models allowed for different intercepts and slopes for each product age and were of the form

log10(APC25) ~ age + hours + age:hours

where **age** was considered as a factor and **hours** as a continuous variable. In addition, it was tested whether age could be modelled as a continuous variable, i.e. to allow for a linear increase with product age. 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 until all predictors in the model remained significant.

Significant effects in sensory characteristics were obtained by fitting linear models (using means rather than medians). The models fitted utilised tasting order and evaluation day as linear effects,[2] while product age and panellist (booth) were used as factors, with no specific implied ordering.[3] The full model for Appearance was of the following form (R notation) and models for the other sensory attributes were similar:

appearance ~ booth + (day + order + day:order) + age

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 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 scores by taking the mean of the replicate microbiological results for each day and product age and plotting them against the corresponding mean score – note that the mean score was used here to avoid display problems which would arise due to the median taking on only a few different values.

4 Results

Microbiological results are presented in Section 4.1

Results from the sensory evaluations are presented in Sections 4.2-4.4, 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 4.6.

All the statistical models fitted and their results can be found in Appendix 6: Statistical Analyses.

4.1 Microbiological Results

4.1.1 Aerobic Plate Count at 25℃

A graph of the $\log_{10}$ APC, incubated at 25℃, over time is presented in Figure 1. From the graph and the analysis the following observations can be made:

- There is good agreement between the microbiological results obtained for **pieces** samples and from **slices** samples collected immediately after slicing (P-value = 0.3505).
- The increase of $\log_{10}$ APC over time is linear with a rate of growth of 0.0176 cfu/g per hour or 0.42 cfu/g per day.
- The starting levels (Day 0) of $\log_{10}$ APC increase with the age of the lamb shoulder (P-value < 0.001). The increase in the starting levels was not linear (P-value < 0.001), which can also be seen from the following summary:
    - Age 13: Average starting level = 3.07 $\log_{10}$ cfu/g
    - Age 31: Average starting level = 4.16 $\log_{10}$ cfu/g

[2] This was done to assess a general trend (increase/decrease) over days and order of tasting rather than just differences between one day/taste order and another.
[3] Product age is confounded with the animal differences (origin, feed, etc) and hence it was included as a factor rather than a linear effect.

- Age 34: Average starting level = 5.65 $\log_{10}$ cfu/g
- Age 35: Average starting level = 5.94 $\log_{10}$ cfu/g

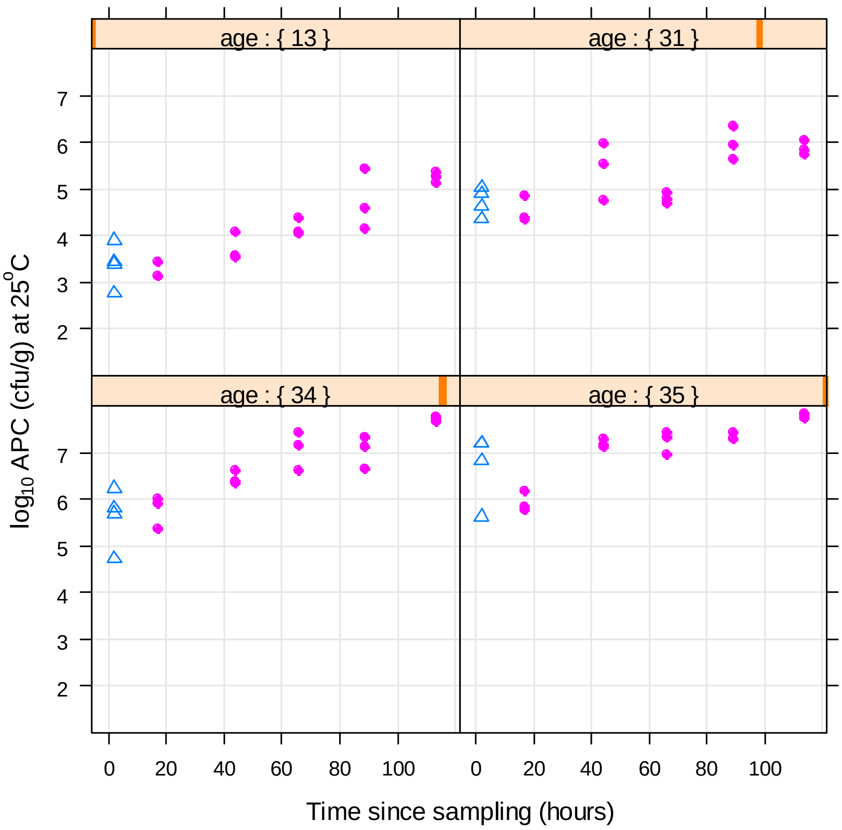

Figure 1: Aerobic Plate Counts, incubated at 25℃, over time (see description for variable "Hours") for the four different ages of lamb shoulders – dots indicate slices; triangles indicate pieces.

4.1.2 Aerobic Plate Count at 35℃

A graph of the $\log_{10}$ APC, incubated at 35℃, over time is presented in Figure 2. From the graph and the analysis the following observations can be made:

- There is good agreement between the microbiological results obtained for **pieces** samples and from **slices** samples collected immediately after slicing (P-value = 0.5785).
- The increase of $\log_{10}$ APC over time is linear with a rate of growth of 0.0177 cfu/g per hour or 0.42 cfu/g per day.
- The starting levels of $\log_{10}$ APC increase with the age of the lamb shoulder (P-value < 0.001). The increase in the starting levels was not linear (P-value < 0.001), which can also be seen from the following summary:
  - Age 13: Average starting level = 2.93 $\log_{10}$ cfu/g
  - Age 31: Average starting level = 4.14 $\log_{10}$ cfu/g
  - Age 34: Average starting level = 5.57 $\log_{10}$ cfu/g
  - Age 35: Average starting level = 5.84 $\log_{10}$ cfu/g

- Based on the summary results and a model to assess the differences (results not shown) it can be concluded there is no difference in the growth rate between the Aerobic Plate Counts incubated at 25 and 35℃; however, on average APC at 25℃ was 0.10 $\log_{10}$ cfu/g higher.

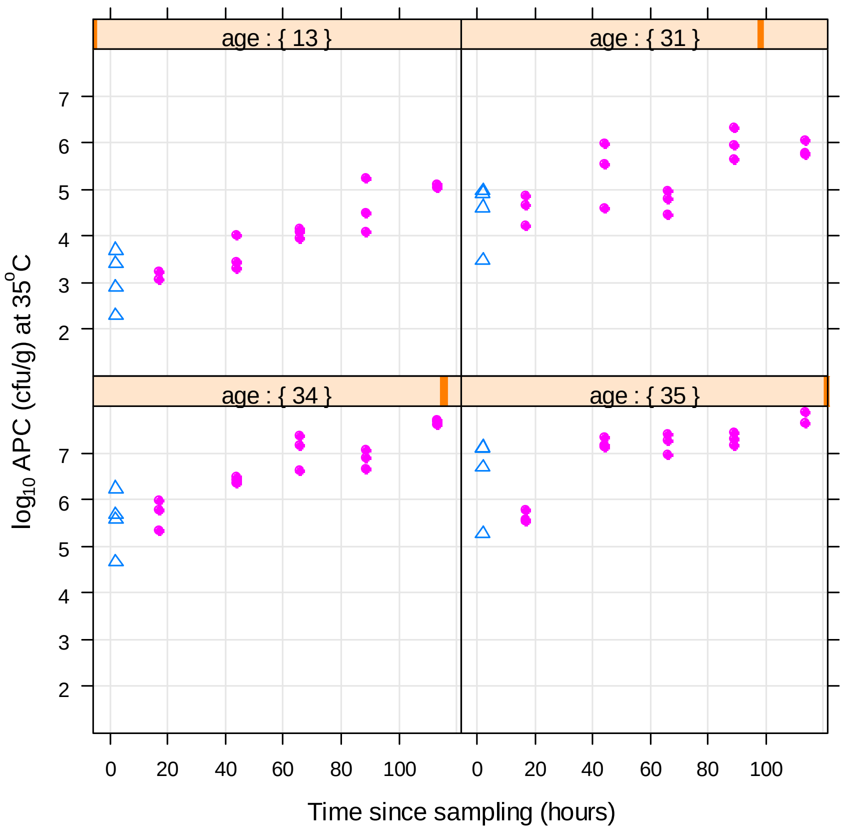

Figure 2: Aerobic Plate Counts, incubated at 35℃, over time (see description for variable "Hours") for the four different ages of lamb shoulders – dots indicate slices; triangles indicate pieces.

4.1.3 Lactic Acid Bacteria at 25℃

A graph of the $\log_{10}$ LAB, when incubated at 25℃, over time is presented in Figure 3. From the graph and the analysis the following observations can be made:

- There is good agreement between the microbiological results obtained for **pieces** samples and from **slices** samples collected immediately after slicing (P-value = 0.3505).
- The increase of $\log_{10}$ LAB over time is linear with a rate of growth of 0.0190 cfu/g per hour or 0.45 cfu/g per day, which is marginally higher than that observed for APC at 25℃.
- The starting levels of $\log_{10}$ LAB increase with the age of the lamb shoulder (P-value < 0.001). The increase in the starting levels was not linear (P-value < 0.001), which can also be seen from the following summary:
    - Age 13: Average starting level = 2.09 $\log_{10}$ cfu/g
    - Age 31: Average starting level = 4.05 $\log_{10}$ cfu/g
    - Age 34: Average starting level = 5.45 $\log_{10}$ cfu/g
    - Age 35: Average starting level = 5.59 $\log_{10}$ cfu/g

- The largest difference in starting levels between LAB and APC at 25℃ is observed for the product which had been vacuum packed for the least amount of time (age = 13).
- Based on the summary results and a model to assess the differences (results not shown) it can be concluded there is no difference in the growth rate between the APC and LAB at 25℃; however, on average APC at 25℃ was 0.11 $\log_{10}$ cfu/g higher.

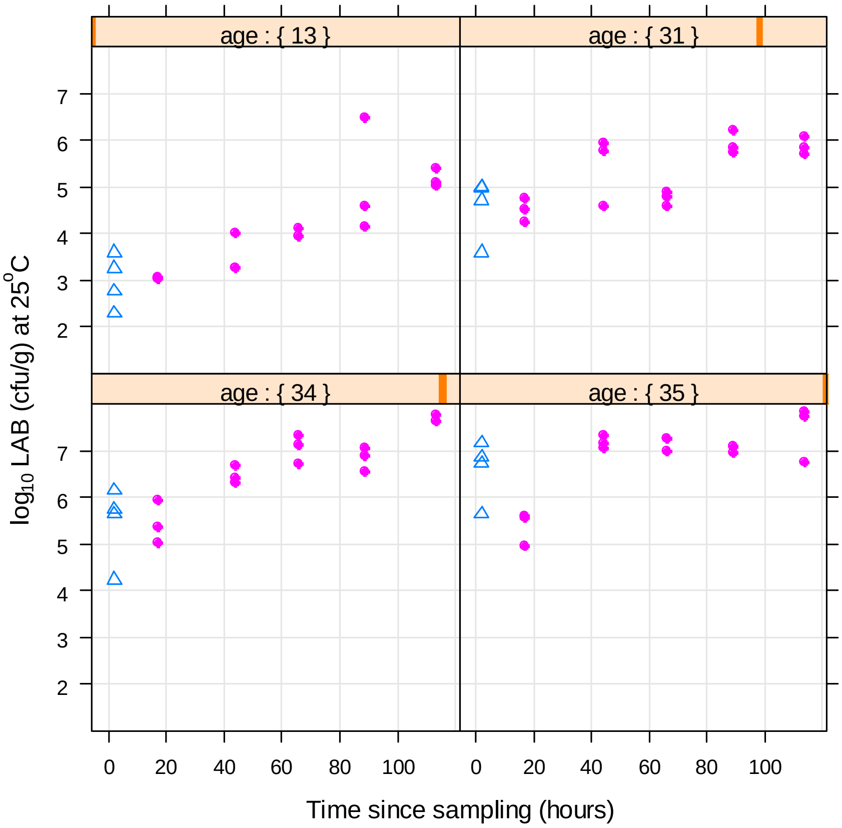

Figure 3: Lactic Acid Bacteria, incubated at 25℃, over time (see description for variable "Hours") for the four different ages of lamb shoulders – dots indicate slices; triangles indicate pieces.

4.1.4 Lactic Acid Bacteria at 35℃

A graph of the $\log_{10}$ LAB, when incubated at 35℃, over time is presented in Figure 4. From the graph and the analysis the following observations can be made:

- There is poor agreement between the microbiological results obtained for **pieces** samples and from **slices** samples collected immediately after slicing (P-value = 0.001). This is contrary to the observations made for LAB incubated at 25℃ and the APC results at 25℃ and 35℃.
- The increase of $\log_{10}$ LAB over time is adequately described by a straight line, despite the patterns in growth for product ages 34 and 35. The rate of growth of 0.0315 cfu/g per hour or 0.76 cfu/g per day, which is considerably higher than that observed for LAB tests incubated at 25℃.
- The starting levels of $\log_{10}$ LAB increase with the age of the lamb shoulder (P-value < 0.001). The increase in the starting levels was not linear (P-value = 0.0165), which can also be seen from the following summary:

- Age 13: Average starting level = 1.51 $\log_{10}$ cfu/g
- Age 31: Average starting level = 2.52 $\log_{10}$ cfu/g
- Age 34: Average starting level = 2.79 $\log_{10}$ cfu/g
- Age 35: Average starting level = 4.00 $\log_{10}$ cfu/g

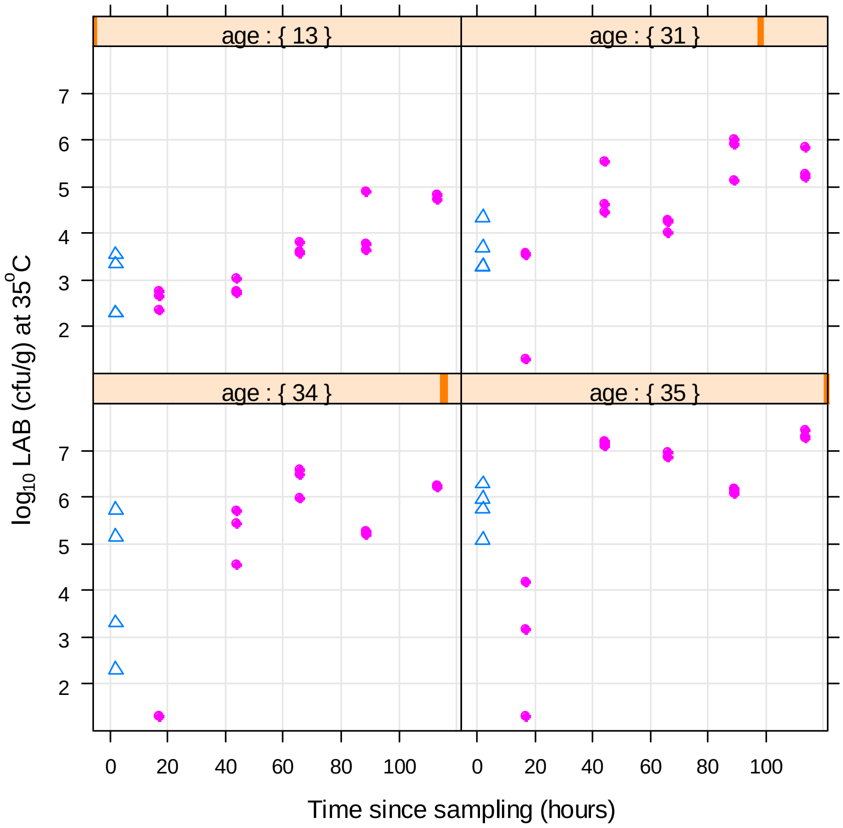

Figure 4: Lactic Acid Bacteria, incubated at 35°C, over time (see description for variable "Hours") for the four different ages of lamb shoulders – dots indicate slices; triangles indicate pieces.

4.2 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.

4.2.1 Appearance

Bar charts of the actual scores for each age and day are displayed in Figure 5. The predicted appearance scores from the fitted model are presented in Table 1. From the model fitted to the appearance score the following conclusions can be drawn:

- There were significant differences between panellists (P-value < 0.001) with Panellist 2 (booth 5) generally scoring highest and Panellist 3 (booth 7) scoring lowest.
- Differences between the products of different ages were significant (P-value < 0.001); the product with age 34 scored highest (4.2) and age 35 scored lowest (3.5) on average.

- The order of scoring was marginally significant (P-value = 0.052), indicating that product tasted last scored an average 0.4 units lower than the product tasted first.
- There were no significant changes (P-value = 0.90) in the score for each product over the duration of the trial; product on Day 4 scored as well as product on Day 1.

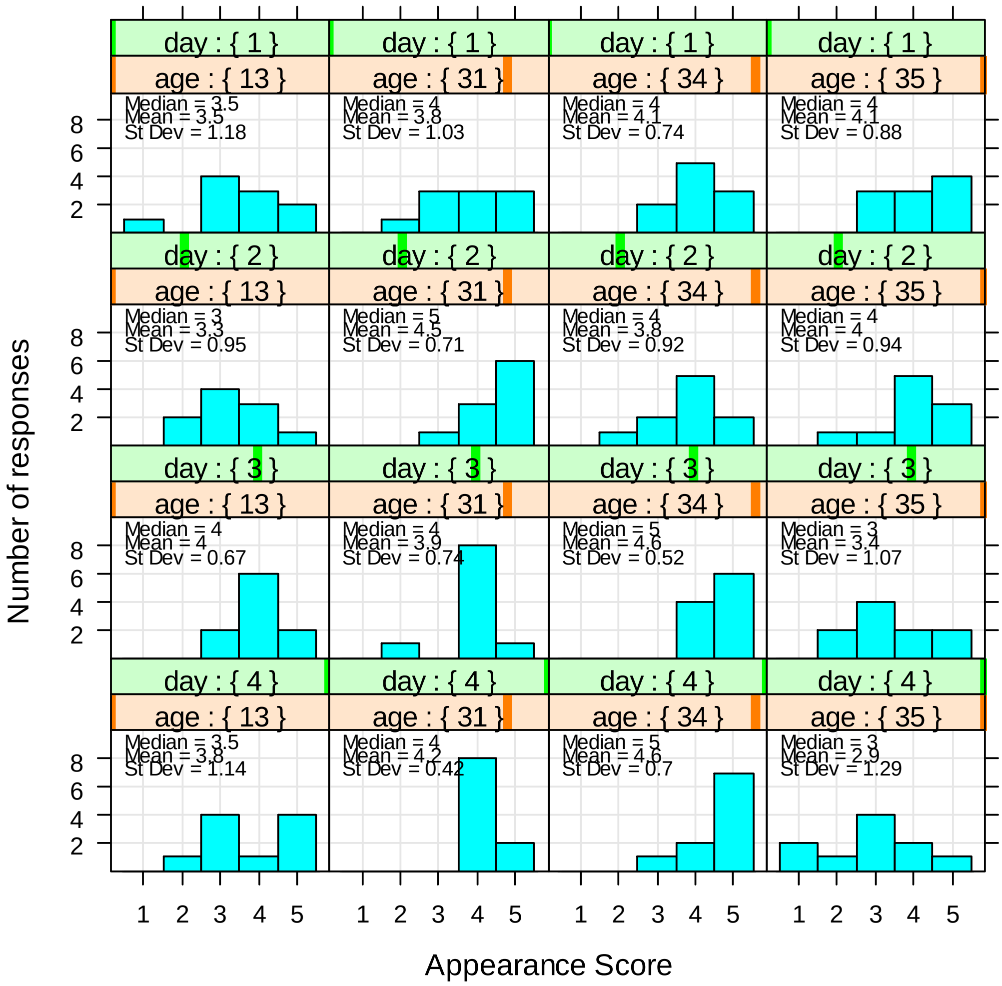

Figure 5: Bar chart of the Appearance scores (raw product) for each lamb shoulder age (in columns) and assessment day (in rows) – 1 = Not Good, 5 = Good.

Table 1: Predicted appearance score for each combination of lamb shoulder age and evaluation order, the two significant predictors in the model (ignoring panellists).

	Evaluation Order			
	1	**2**	**3**	**4**
Red (13 days)	3.9	3.8	3.7	3.6
Green (31 days)	4.3	4.2	4.1	4.0
Yellow (34 days)	4.4	4.3	4.2	4.1
Blue (35 days)	3.7	3.6	3.5	3.4

4.2.2 Colour

Bar charts of the actual scores for each age and day are displayed in Figure 6. The predicted colour scores from the fitted model are presented in Table 2. From the model fitted to the colour score the following conclusions can be drawn:

- There were significant differences between panellists (P-value < 0.001) with Panellist 7 (booth 11) generally scoring highest and Panellist 10 (booth 14) scoring lowest.
- Differences between the products of different ages were significant (P-value < 0.001); the product with age 31 scored highest (4.5 marginally higher than age 34) and age 35 scored lowest (3.9) on average.
- The order of scoring was significant (P-value = 0.02), indicating that product assessed last scored an average 0.3 units lower than the product assessed first.
- There were no significant changes (P-value = 0.24) in the score for each product over the duration of the trial; product on Day 4 scored as well as product on Day 1.

These results are similar to those for the appearance score, which is expected since both attributes relate to the visual perception of the product.

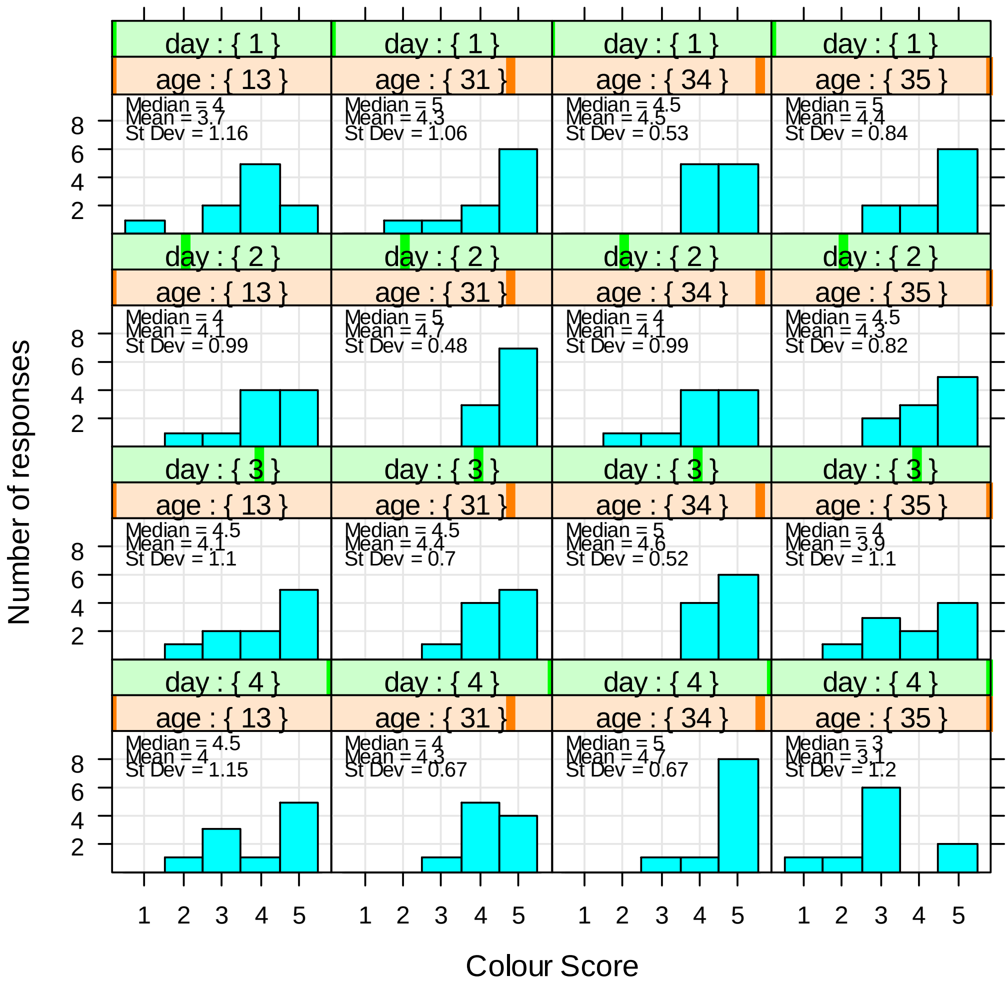

Figure 6: Bar chart of the Colour scores (raw product) for each lamb shoulder age (in columns) and assessment day (in rows) – 1 = Not Good, 5 = Good.

Table 2: Predicted colour score for each combination of lamb shoulder age and evaluation order, the two significant predictors in the model (ignoring panellists).

	Evaluation Order			
	1	**2**	**3**	**4**
Red (13 days)	4.2	4.1	4.0	3.9
Green (31 days)	4.6	4.5	4.4	4.3
Yellow (34 days)	4.6	4.5	4.4	4.3
Blue (35 days)	4.0	3.9	3.8	3.7

4.3 Would a consumer cook it?

The smell 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 age and day are displayed in Figure 7. The predicted smell scores from the fitted model are presented in Table 3. From the model fitted to the smell score the following conclusions can be drawn:

- There were significant differences between panellists (P-value < 0.001) with Panellist 1 (booth 5) generally scoring highest and Panellist 9 (booth 13) scoring lowest.
- Differences between the products of different ages were marginally significant (P-value = 0.07); the product with age 35 scored highest (4.0) and age 13 scored lowest (3.7) on average.
- The order of scoring was not significant (P-value = 0.51).
- There were significant changes (P-value = 0.006) in the score for each product over the duration of the trial; product on Day 4 scoring an average of 0.46 units lower than the same product on Day 1.

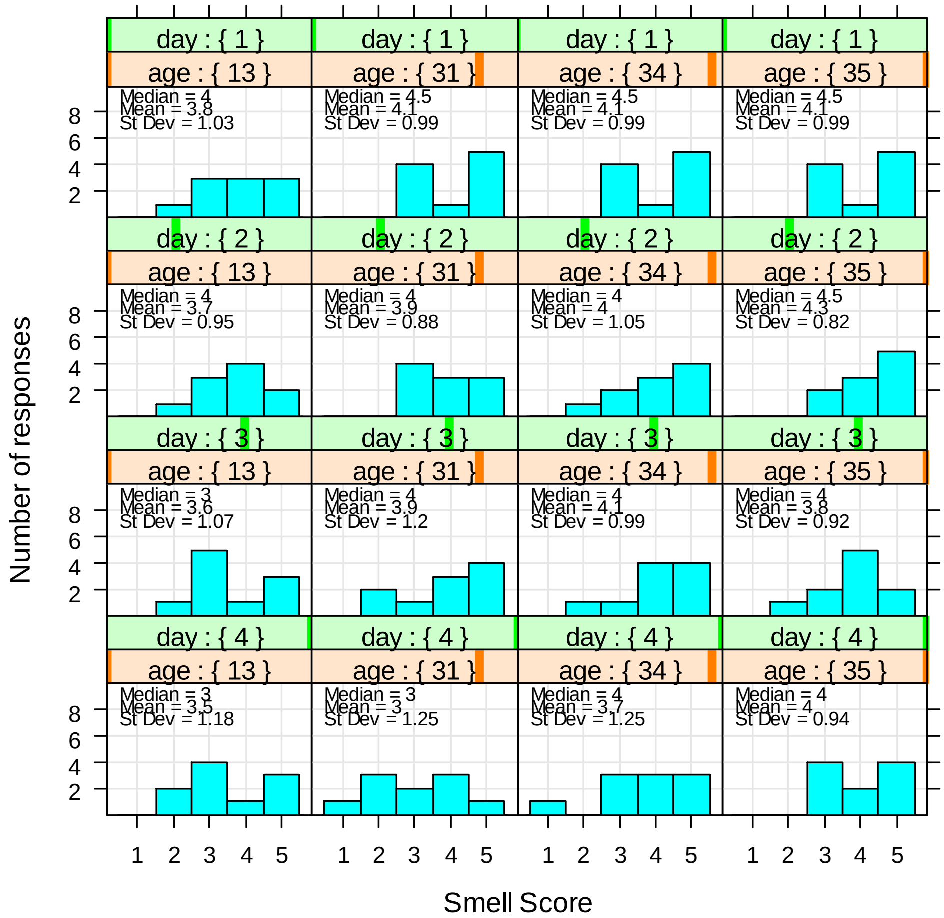

Figure 7: Bar chart of the Smell scores (raw product) for each lamb shoulder age (in columns) and assessment day (in rows) – 1 = Not Good, 5 = Good.

Table 3: Predicted smell score for each combination of lamb shoulder age and evaluation day, the two significant predictors in the model (ignoring panellists).

	Day 1	**Day 2**	**Day 3**	**Day 4**
Red (13 days)	3.9	3.7	3.6	3.4
Green (31 days)	4.0	3.8	3.6	3.5
Yellow (34 days)	4.2	4.1	3.9	3.7
Blue (35 days)	4.3	4.1	4.0	3.8
Total	*4.1*	*3.9*	*3.8*	*3.6*

4.4 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 sec) cooked on both sides. This was similar to the way a consumer would experience the product at home.

4.4.1 Taste

Bar charts of the actual scores for each age and day are displayed in Figure 8. The predicted taste scores from the fitted model are presented in Table 4. From the model fitted to the taste score the following conclusions can be drawn:

- There were significant differences between panellists (P-value < 0.001) with Panellists 1 and 5 (booths 5 and 9) generally scoring highest and Panellists 2 and 3 (booths 6 and 7) scoring lowest.
- Differences between the products of different ages were significant (P-value = 0.03); the product with age 35 scored highest (4.2) and age 13 scored lowest (3.6) on average.
- The order of scoring was not significant (P-value = 0.33).
- There were significant changes (P-value = 0.01) in the score for each product over the duration of the trial; product on Day 4 scoring an average of 0.53 units lower than the same product on Day 1.

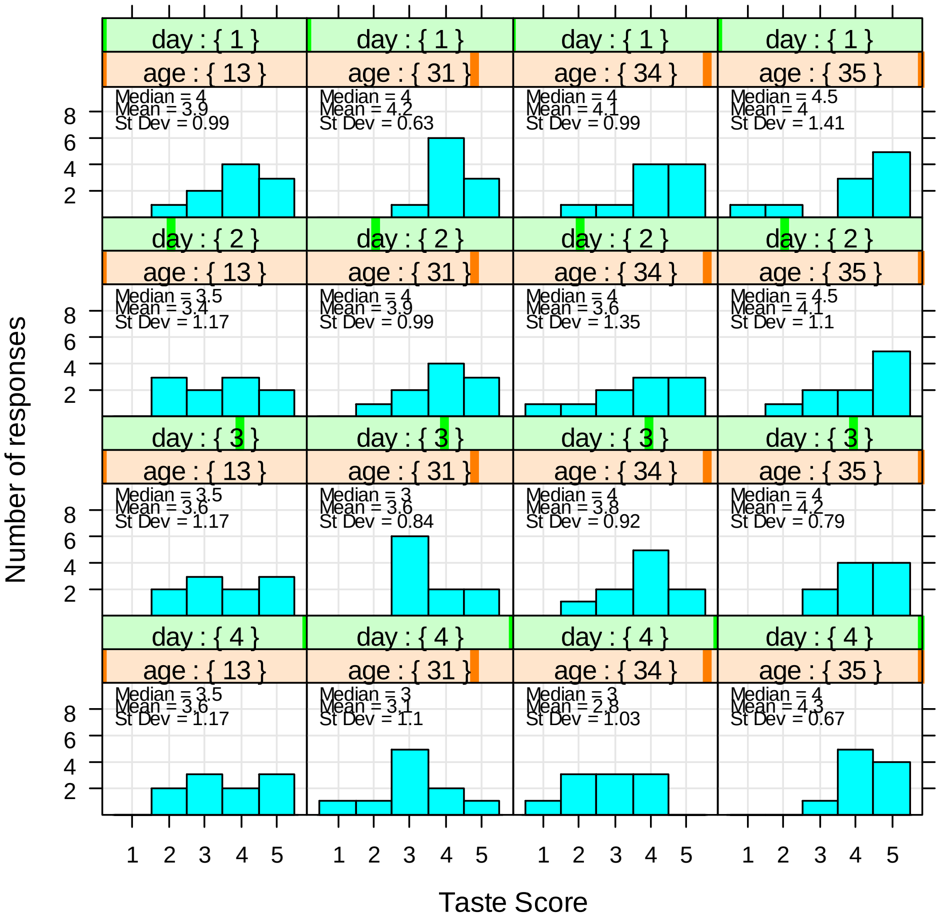

Figure 8: Bar chart of the Taste scores (cooked product) for each lamb shoulder age (in columns) and assessment day (in rows) – 1 = Not Good, 5 = Good.

Table 4: Predicted taste score for each combination of lamb shoulder age and evaluation day, the two significant predictors in the model (ignoring panellists).

	Day 1	Day 2	Day 3	Day 4
Red (13 days)	3.9	3.7	3.5	3.4
Green (31 days)	4.0	3.8	3.6	3.4
Yellow (34 days)	3.8	3.7	3.5	3.3
Blue (35 days)	4.4	4.2	4.1	3.9
Total	*4.0*	*3.9*	*3.7*	*3.5*

4.4.2 Texture

Bar charts of the actual scores for each age and day are displayed in Figure 9. The predicted texture scores from the fitted model are presented in Table 5. From the model fitted to the texture score the following conclusions can be drawn:

- There were significant differences between panellists (P-value < 0.001) with Panellist 7 (booth 11) generally scoring highest and Panellists 2 and 3 (booths 6 and 7) scoring lowest.
- There were no significant differences between products of different ages (P-value = 0.19).
- The order of scoring was not significant (P-value = 0.91).
- There were significant changes (P-value = 0.006) in the score for each product over the duration of the trial; product on Day 4 scoring an average of 0.53 units lower than the same product on Day 1.

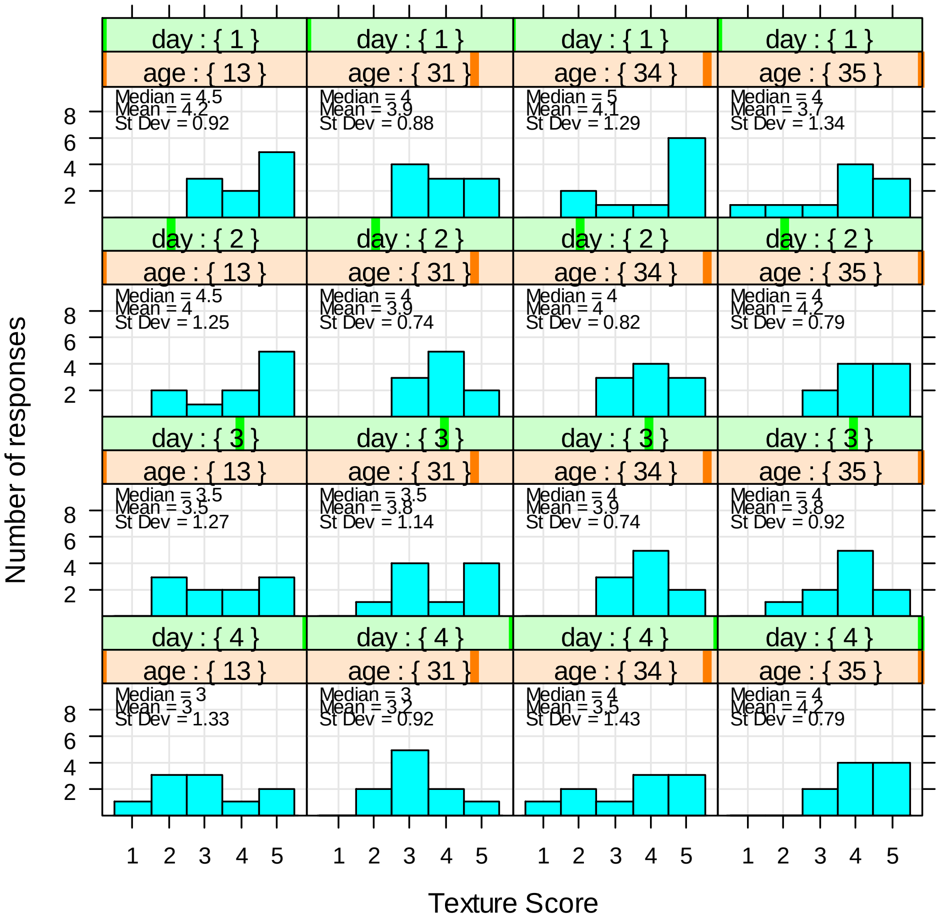

Figure 9: Bar chart of the Texture scores (cooked product) for each lamb shoulder age (in columns) and assessment day (in rows) – 1 = Not Good, 5 = Good.

Table 5: Predicted texture score for each evaluation day, the only significant predictors in the model (ignoring panellists).

	Day 1	**Day 2**	**Day 3**	**Day 4**
Total	*4.1*	*3.9*	*3.7*	*3.5*

4.5 Overall Assessment

Bar charts of the actual scores for each age and day are displayed in Figure 10. The predicted overall scores from the fitted model are presented in Table 6. From the model fitted to the overall score the following conclusions can be drawn:

- There were significant differences between panellists (P-value < 0.001) with Panellist 1 (booth 5) generally scoring highest and Panellist 2 (booth 6) scoring lowest.
- There were no significant differences between products of different ages (P-value = 0.93).
- The order of scoring was not significant (P-value = 0.16).
- There were significant changes (P-value = 0.016) in the score for each product over the duration of the trial; product on Day 4 scoring an average of 0.46 units lower than the same product on Day 1.

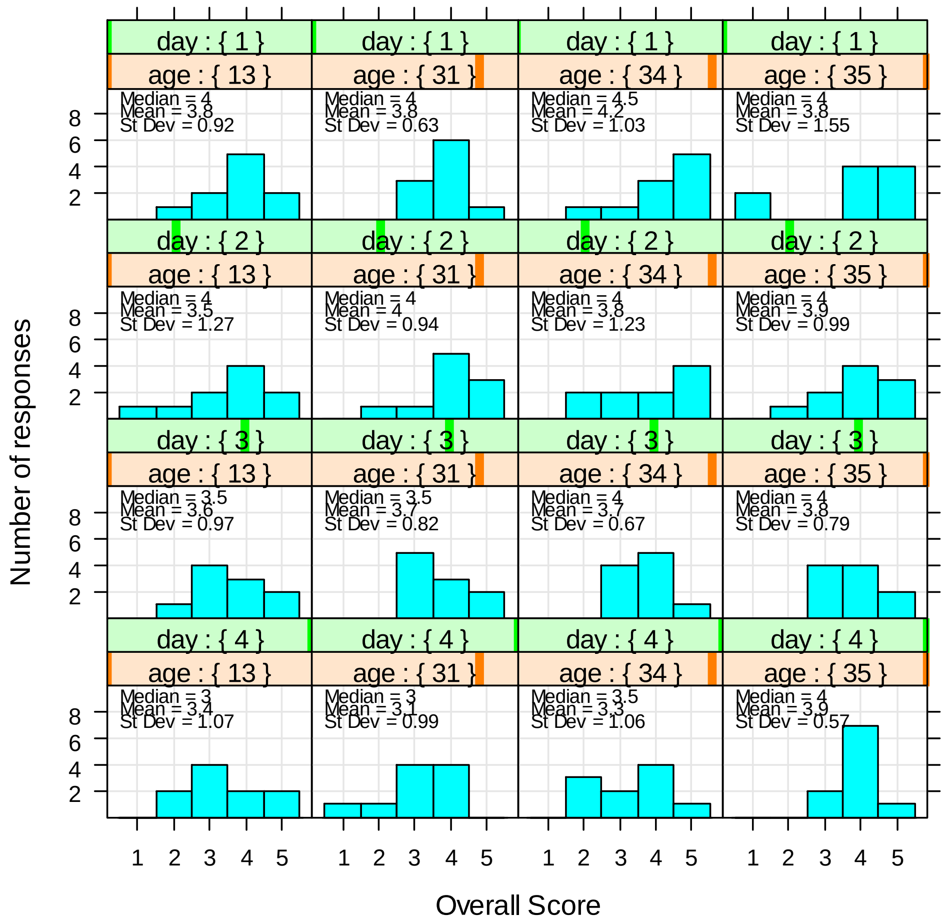

Figure 10: Bar chart of the Overall score for each lamb shoulder age (in columns) and assessment day (in rows) – 1 = Not Good, 5 = Good.

Table 6: Predicted overall score for each evaluation day, the only significant predictors in the model (ignoring panellists).

	Day 1	Day 2	Day 3	Day 4
Total	*3.9*	*3.8*	*3.6*	*3.5*

4.6 Comparing Microbiological and Sensory results

As indicated in Section 3.6, the comparison of microbiological results versus sensory results was undertaken by calculating the mean for both results for each product age and evaluation day.[4] The hypothesis is that microbiological loads (APC or LAB) are related to the sensory perception of consumers.

To assess this, the various sensory attribute scores were plotted against $\log_{10}$ APC and $\log_{10}$ LAB at 25 and 35℃ – these plots are presented in F igures 11-14, respectively.

Given the similarity in the microbiological results (Section 4.1), it is not surprising that the four plots also display similar patterns. In particular, from these graphs it can be seen that generally (ignoring product age) there appears to be little or no relationship between the average microbiological quality and the average score (all sensory characteristics).[5]

For some, but not all, combinations of sensory characteristic and product age there do appear to be decreasing relationships (higher microbial load is associated with lower score), e.g. smell, texture and overall scores for red (13 day old) and yellow (34 day old). However, these observations are not consistent across all product ages and sensory characteristics and together with the use of an untrained sensory panel, should be treated cautiously.

[4] It is recognised that this is not quite accurate since the microbiological analysis was generally done 14 hours after sensory evaluation took place. However, the only link between the two observations is the day on which they were collected. Given the constant rate of growth observed in Section 4.1 it can be expected that the misalignment between microbiological and sensory testing would shift the results by a constant amount and hence would not impact on any relationship, if present.

[5] This was confirmed by fitting a quadratic model (to allow for the drops of the “blue” product) to each sensory attribute (output not included). None of the models resulted in any significant relationships.

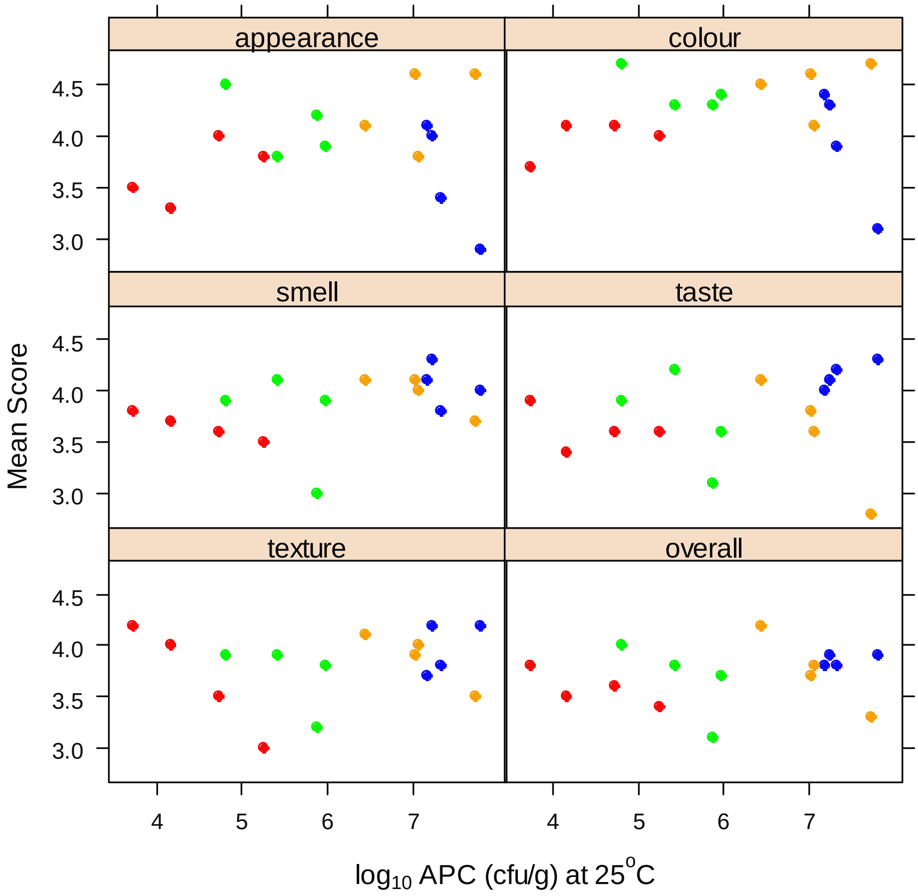

Figure 11: Scatter plot of the sensory scores versus $\log_{10}$ APC (at 25℃) – the different coloured points indicate different product ages (red = 13 days old, green = 31 days old, yellow = 34 days old, blue = 35 days old).

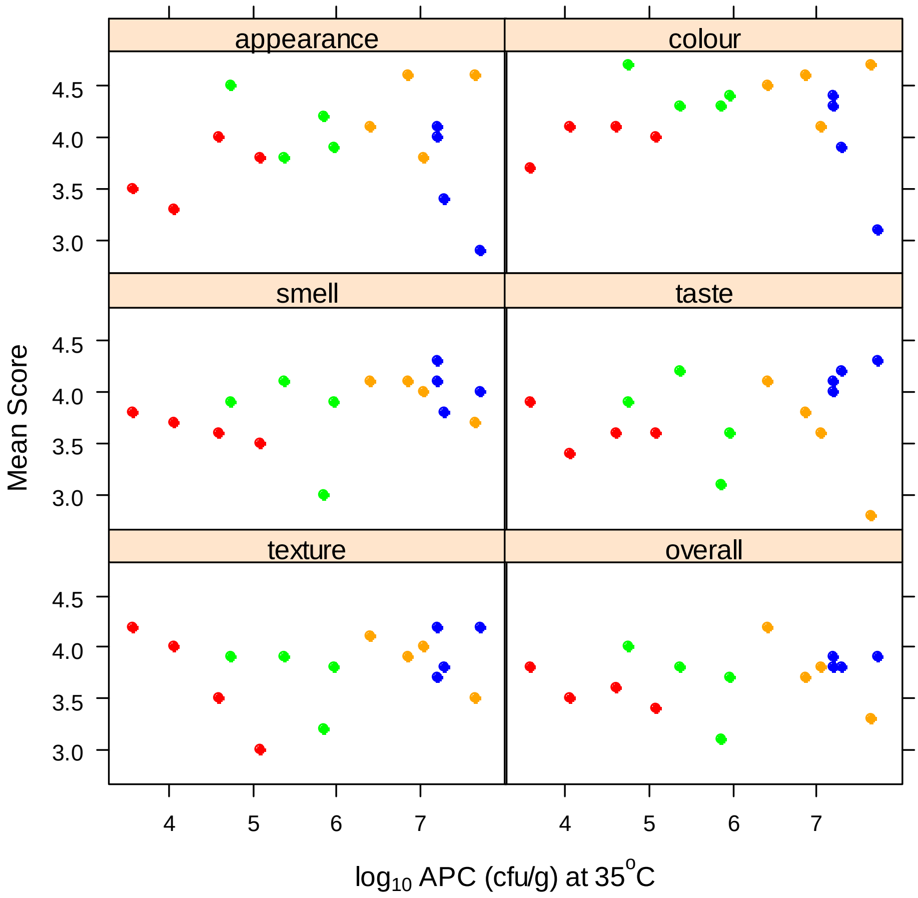

Figure 12: Scatter plot of the sensory scores versus log_{10} APC (at 35°C) – the different coloured points indicate different product ages (red = 13 days old, green = 31 days old, yellow = 34 days old, blue = 35 days old).

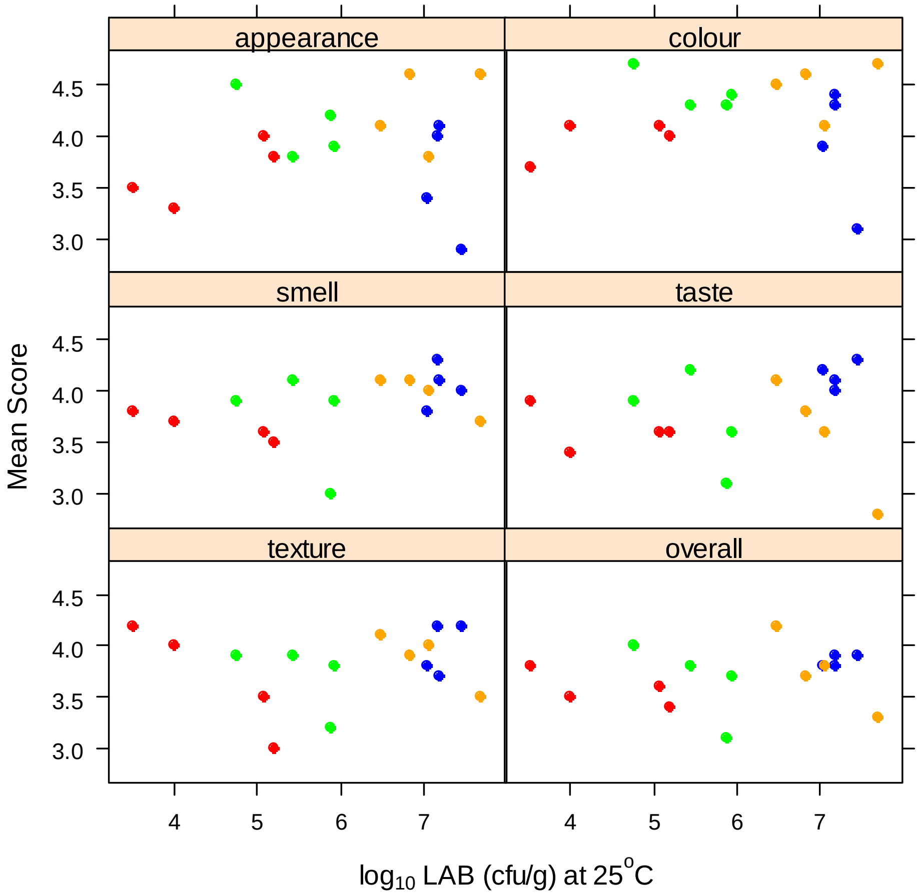

Figure 13: Scatter plot of the sensory scores versus the log_{10} LAB (at 25°C) – the different coloured points indicate different product ages (red = 13 days old, green = 31 days old, yellow = 34 days old, blue = 35 days old).

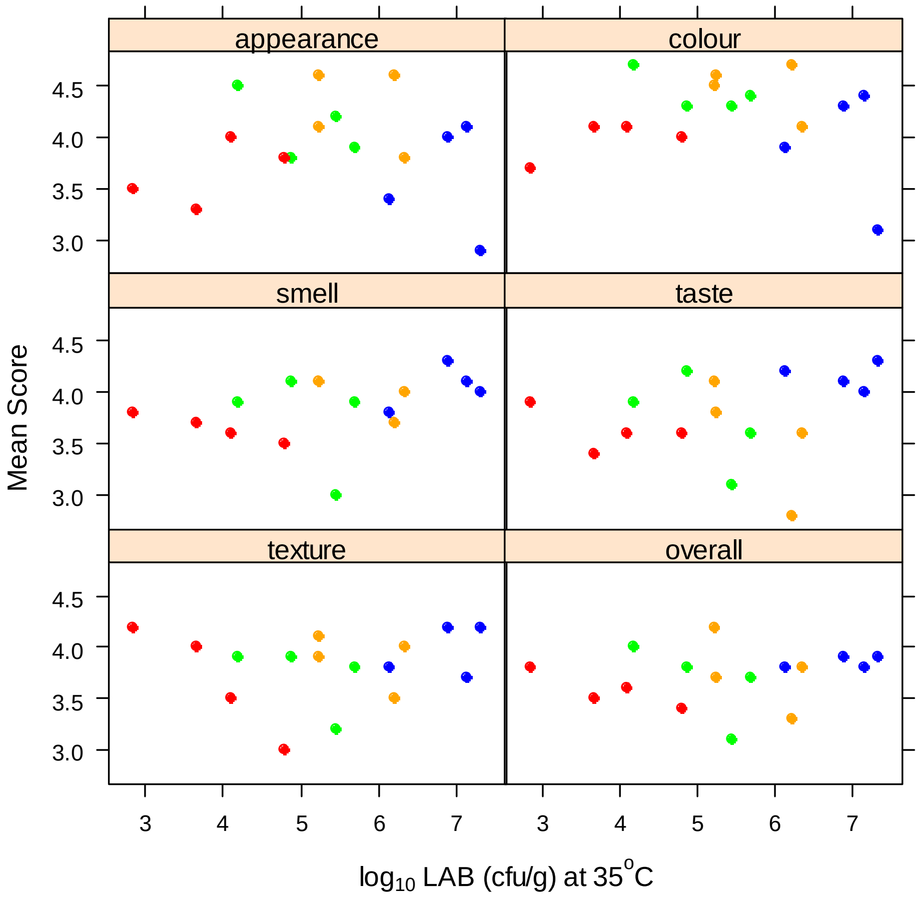

Figure 14: Scatter plot of the sensory scores versus the log_{10} LAB (at 35°C) – the different coloured points indicate different product ages (red = 13 days old, green = 31 days old, yellow = 34 days old, blue = 35 days old).

5 Discussion

The product sourced for this trial was the same as that usually sent to Japan. The only exception was in relation to the age of the product – four different ages were used in this trial. This was done to assess the microbiological impact of vacuum packed storage of lamb shoulders. While product which had been vacuum packed for longer resulted in higher microbiological counts, the relationship between product age and microbiology could not be summarised in a simple linear manner. However, irrespective of product age, the results indicate that the majority of microbiological flora consists of lactic acid producing bacteria. In fact, APC at 25°C was consistently higher than LAB at 25°C by 0.11 log_{10} cfu/g, which equates to LAB making up the majority of APC across the four day evaluation period.

With respect to the current Japanese requirements, product which had been vacuum packed for 13 days and had mean APC of approximately 3 log_{10} cfu/g would only result in a shelf-life of approximately three days. The oldest product used in this trial had been vacuum packed for 35 days and had initial levels of APC were almost 6 log_{10} cfu/g, which would result in a shelf-life of about one day. Given that it takes approximately 25-30 days for Australian lamb shoulders to reach Japan, it can be expected that under current processing and transport conditions and Japanese testing arrangements, the shelf-life in Japan will be short.

Despite the changes in microbiology throughout the storage trial, the changes in sensory scores appear to be unrelated to the microbiological results. In particular, the high levels of APC and LAB were not related to spoilage of the product. Anecdotally, while some participants scored some products lower than might be expected, all panellists indicated verbally after the sessions that they were very happy with all product samples. Some panellists wanted to know where they could purchase this sliced lamb meat product in Australia and participants were more than happy to take home unopened packs of meat.

Nevertheless, some sensory attributes scored lower, by ½ a score, with longer storage time – these included smell, taste, texture and the overall impression of the product as shown in Table 7. Of note is the effect of product age – while the oldest product was the least appealing from a visual perspective, it tended to be the preferred in terms of smell and taste. A possible explanation for this difference is the raw material (breed, feed) rather than the age of the product. For example, diet has been associated with flavour intensity (e.g. Crouse *et al.* 1981) and also effects on colour, odour and flavour (research being undertaken at the University of Adelaide as reported in The Adelaidean, June 2008).

Table 7: Summary of results from sensory evaluations

	Product Age	Order of Evaluation	Storage Duration
Appearance	Significant Lowest: age 35 Highest: age 34	Marginally Significant Last scored 0.40 lower than first	Not Significant
Colour	Significant Lowest: age 35 Highest: age 31	Significant Last scored 0.40 lower than first	Not Significant
Smell	Marginally Significant Lowest: age 13 Highest: age 35	Not Significant	Significant Day 4 scored 0.46 lower than Day 1
Taste	Significant Lowest: age 13 Highest: age 35	Not Significant	Significant Day 4 scored 0.53 lower than Day 1
Texture	Not Significant	Not Significant	Significant Day 4 scored 0.53 lower than Day 1
Overall	Not Significant	Not Significant	Significant Day 4 scored 0.46 lower than Day 1

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, the meat on all days looked fresh and without darkening or discolorations (Appendix 4: Photographs). Nevertheless, on Day 2 Panellist 7 scored the colour of the red pack as a 5, with the comment “good colour”, while Panellist 8 scored the identical pack as a 2 with the comment “colour was too dark”. 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.

6 Success in Achieving Objectives

The objectives of this work have been achieved as follows:

- Lamb shoulders which had been vacuum packed for different lengths of time have been prepared, sliced and stored in the same way as is currently done in Japan.
- The sliced product has been evaluated microbiologically using Aerobic Plate Counts and Lactic Acid Bacteria counts under two incubation temperatures.
- The sensory attributes of the sliced product have been evaluated using an untrained sensory panel of Japanese consumers.

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 Kate Neath for the information she provided about product and sensory testing in Japan and Dr John Sumner for organising and delivering the vacuum packed lamb shoulders 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

Gender	Age	Region	Lived in Australia	Eaten Lamb	Last Time eaten Lamb	Eaten Lamb Where?
F	20	Kanto	<6months	3-5 times	>2 years ago	Restaurant in Japan
F	20	Chuba	6-12 months	3-5 times	within last month	At home AU
F	30	Tohoku/Kanto	1-2 year	>10 times	within last month	At home AU
F	30	Kanto	6-12 months	>10 times	within last 6 months	At home & restaurant in AU At home & restaurant in Japan
F	40	Kanto	1-2 years	>10 times	within last year	Restaurant in NZ
M	20	Kansai (Osaka)	6-12 months	>10 times	This week	At home AU
M	20	Kansai	<6months	3-5 times	within last month	At home AU
M	20	Kyusha	1-2 years	5-10 times	within last year	At home AU
M	30	Chuba	>5 years	5-10 times	within last year	At home AU
M	40	Chugoku, Kanto, Kansai	<6 months	>10times	within last month	At Restaurant in AU

9.2 Appendix 2: Microbiological Data

Age	Day	Type	Sample	APC25	APC35	LAB25	LAB35
13	0	pieces	1	600	200	<200	<200
13	0	pieces	2	2800	2600	1800	3600
13	0	pieces	3	7900	5100	4000	2200
13	0	pieces	4	2500	800	600	<200
13	0	slices	1	1400	1200	1100	220
13	0	slices	2	2700	1700	1200	560
13	0	slices	3	1400	1200	1100	440
13	1	slices	1	3400	2000	1800	600
13	1	slices	2	3900	2700	1900	520
13	1	slices	3	12000	10000	10000	1100
13	2	slices	1	11000	12000	9200	4000
13	2	slices	2	12000	8600	8600	3800
13	2	slices	3	25000	14000	13000	6400
13	3	slices	1	270000	170000	3000000	76000
13	3	slices	2	14000	12000	14000	4400
13	3	slices	3	40000	32000	38000	6000
13	4	slices	1	180000	130000	130000	52000
13	4	slices	2	240000	130000	260000	68000
13	4	slices	3	140000	110000	110000	68000
31	0	pieces	1	110000	92000	98000	5000
31	0	pieces	2	79000	85000	100000	22000
31	0	pieces	3	23000	3000	4000	<2000
31	0	pieces	4	43000	42000	52000	<2000
31	0	slices	1	75000	75000	56000	<20
31	0	slices	2	25000	47000	34000	3800
31	0	slices	3	22000	17000	18000	3400
31	1	slices	1	56000	40000	40000	28000
31	1	slices	2	950000	920000	880000	340000
31	1	slices	3	350000	360000	580000	42000
31	2	slices	1	85000	92000	60000	20000
31	2	slices	2	50000	29000	38000	10000
31	2	slices	3	62000	64000	78000	18000
31	3	slices	1	2300000	2100000	1700000	1000000
31	3	slices	2	430000	440000	540000	140000
31	3	slices	3	870000	910000	680000	820000
31	4	slices	1	1100000	1100000	1200000	700000
31	4	slices	2	690000	550000	520000	190000
31	4	slices	3	550000	620000	720000	160000
34	0	pieces	1	1700000	1700000	1400000	540000
34	0	pieces	2	500000	370000	560000	140000
34	0	pieces	3	54000	45000	17000	2000
34	0	pieces	4	660000	480000	440000	200
34	0	slices	1	1000000	580000	880000	<20
34	0	slices	2	240000	220000	240000	<20
34	0	slices	3	820000	920000	110000	<20
34	1	slices	1	4000000	3000000	5000000	500000
34	1	slices	2	2200000	2500000	2100000	36000
34	1	slices	3	2400000	2300000	2500000	280000
34	2	slices	1	15000000	15000000	13000000	3000000
34	2	slices	2	4200000	4000000	5400000	940000
34	2	slices	3	26000000	23000000	22000000	3800000
34	3	slices	1	13000000	7600000	7800000	160000
34	3	slices	2	21000000	11000000	11000000	180000

Age	Day	Type	Sample	APC25	APC35	LAB25	LAB35
34	3	slices	3	4400000	4500000	3600000	180000
34	4	slices	1	58000000	41000000	60000000	1600000
34	4	slices	2	48000000	45000000	44000000	1700000
34	4	slices	3	55000000	50000000	44000000	1600000
35	0	pieces	1	16000000	13000000	15000000	920000
35	0	pieces	2	16000000	13000000	7200000	560000
35	0	pieces	3	430000	190000	440000	120000
35	0	pieces	4	6800000	5000000	5400000	1900000
35	0	slices	1	610000	370000	400000	1400
35	0	slices	2	700000	350000	360000	15000
35	0	slices	3	1500000	610000	92000	<20
35	1	slices	1	14000000	15000000	14000000	12000000
35	1	slices	2	19000000	21000000	22000000	16000000
35	1	slices	3	13000000	13000000	11000000	14000000
35	2	slices	1	21000000	18000000	18000000	7000000
35	2	slices	2	27000000	24000000	18000000	9200000
35	2	slices	3	9100000	9000000	10000000	7400000
35	3	slices	1	26000000	28000000	12000000	1500000
35	3	slices	2	19000000	14000000	9000000	1200000
35	3	slices	3	20000000	19000000	12000000	1400000
35	4	slices	1	66000000	76000000	68000000	27000000
35	4	slices	2	55000000	44000000	5800000	19000000
35	4	slices	3	70000000	44000000	56000000	18000000

9.3 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.

9.4 Appendix 4: Photographs

Photographs of the product were taken prior to sensory testing on Days 2, 3, and 4.

Day 2: Red – 13 days old lamb shoulders

Day 2: Green – 31 days old lamb shoulders

Day 2: Yellow – 34 days old lamb shoulders

Day 2: Blue – 35 days old lamb shoulders

Day 3: Red – 13 days old lamb shoulders

Day 3: Green – 31 days old lamb shoulders

Day 3: Yellow – 34 days old lamb shoulders

Day 3: Blue – 35 days old lamb shoulders

Day 4: Red – 13 days old lamb shoulders

Day 4: Green – 31 days old lamb shoulders

Day 4: Yellow – 34 days old lamb shoulders

Day 4: Blue – 35 days old lamb shoulders

9.5 Appendix 5 Sensory Data

Day	Age	Order	Dot	Booth	Appearance	Colour	Small	Taste	Texture	Overall	Comments
1	13	4	Red	5	5	5	5	5	5	5	The appearance & colour is good. The pieces of meat are almost the same size. The pack is more weight than other packs. The colour look like more fresh. The meat is soft and good texture. However I would like to add pepper, salt & soy sauce plus wasabi.
1	13	4	Red	6	5	4	4	4	3	3	
1	13	4	Red	7	3	5	5	3	3	3	uneven pieces, colour dark, sweet, sometimes taste good sometimes not, little tough, not good for korean bbq
1	13	4	Red	8	3	3	3	4	4	4	colour was too dark red, looks like tough but was in fact sweet and tender, okay but not bad smell
1	13	4	Red	9	4	4	3	4	4	4	not a bad smell but very meaty,white part was tough
1	13	4	Red	10	4	3	4	5	5	4	I think the texture is good for young, but it may be hard for old people
1	13	4	Red	11	4	4	5	3	5	4	comparing all colours of meat, this meat had more fat. Not appealing for those who don't like fat, tender and easy to chew
1	13	4	Red	12	3	4	4	5	5	5	I like this meat best, very tender and delicious, only this meat had different smell
1	13	4	Red	13	3	4	3	4	3	4	colour beautiful but could see lots of blood, strongest smell, not bad, taste strong, little tough
1	13	4	Red	14	1	1	2	2	5	2	couldn't taste much, meat was tender and easy to eat but not delicious, after cooked smell was not appetising
1	31	3	Green	5	4	4	5	5	4	4	The size of the pieces are different to each other. The colour look like bad meat (old meat). The smell is good (not bad smells). The taste is good and the meat is a bit harder than other meat. However the meat bit smell compared to other meat. If possible please add "wasabi-soy sauce". the taste is very good.
1	31	3	Green	6	5	5	4	4	3	4	
1	31	3	Green	7	3	5	5	4	4	4	messy appearance, delicious, smell not strong, taste started good but dissapeared during chewing, little

Day	Age	Order	Dot	Booth	Appearance	Colour	Small	Taste	Texture	Overall	Comments
											tough
1	31	3	Green	8	4	5	3	4	3	3	looks good but meat was tough, smell was less than blue, after I ate it tasted ok
1	31	3	Green	9	5	5	3	4	4	4	a little tough, could smell a little
1	31	3	Green	10	5	5	5	4	5	4	I felt it smelled more than the second one did
1	31	3	Green	11	2	5	5	5	5	4	easier to chew than yellow/blue, couldn’t smell meat
1	31	3	Green	12	3	3	3	3	3	3	the colour was similar to blue meat, could feel typical lamb taste and smell, compared with the other 2.
1	31	3	Green	13	4	4	3	4	3	3	looks fresh but could see lots of blood, smelled a little, at first delicious but after taste was just meat, tough
1	31	3	Green	14	3	2	5	5	5	5	could smell lamb, but I could eat, similar to yellow meat, I will need to try again one day
1	34	1	Yellow	5	4	4	5	4	5	4	The meat is very soft but I would like to add soy-sauce, salt & pepper because the meat if of very light taste
1	34	1	Yellow	6	4	4	3	2	2	2	
1	34	1	Yellow	7	3	5	4	4	3	5	sizes uneven, typical lamb smell, didn’t taste typical lamb, suits for bbq, some meat was tender, some was tough
1	34	1	Yellow	8	3	5	5	5	5	5	couldn’t smell lamb, really similar to japanese pork, meat was tender and delicious
1	34	1	Yellow	9	5	5	3	5	5	5	no smell, meat tender, very delicious easy to eat, could not smell meat, I could smell the wrapper
1	34	1	Yellow	10	5	5	5	4	5	5	Actually I don't like lamb very much because of its smell. However, it was not hard to eat for me. It still smelled when I ate it, but it was not much. Before its cooked it smells ok.
1	34	1	Yellow	11	5	5	5	3	2	3	colour was very shiny good, hard to chew, couldn’t smell lamb so easy to eat
1	34	1	Yellow	12	4	4	3	5	4	4	red colour was beautiful, meat wasn’t too dry and easy to eat
1	34	1	Yellow	13	4	4	3	4	5	4	very tender and nice to eat, couldn’t smell much, easy to eat, could only smell container

Day	Age	Order	Dot	Booth	Appearance	Colour	Small	Taste	Texture	Overall	Comments
1	34	1	Yellow	14	4	4	5	5	5	5	couldn’t imagine the meat was so tender and nice from looking at it, best lamb I have ever tried, felt it was like a korean bbq
1	35	2	Blue	5	5	5	5	5	5	5	The appearance of the meat pieces are always the same. The colour also similar to beef. The smell is good, the meat not smell however. The taste is very good. But I would like to add salt, pepper and soy sauce. If possible please add "wasabi & soy sauce".
1	35	2	Blue	6	5	5	3	1	1	1	I want you to cut a center of lap because I can't smell very well
1	35	2	Blue	7	3	5	5	5	3	5	display not good, didn’t like the white part, delicious, tender but some parts tough
1	35	2	Blue	8	3	4	4	4	4	4	could feel dry texture, no lamb smell, could smell lamb after eating, stronger seasoning would be better
1	35	2	Blue	9	4	5	3	4	4	4	
1	35	2	Blue	10	5	5	5	5	5	5	It smelled less than the first one did. I don't think I'd go for this rather than beef, chicken or pork but I am happy to eat if I'm served this
1	35	2	Blue	11	4	4	5	5	4	4	couldn’t see much fat attracting people on diet, more tender than yellow, couldn’t smell, easy to eat
1	35	2	Blue	12	4	3	3	4	4	4	colour is slightly darker than yellow meat, texture a little tough but I like it
1	35	2	Blue	13	5	5	3	5	5	5	looks shiny/fresh, unfortunately, could only smell container
1	35	2	Blue	14	3	3	5	2	2	1	I could smell typical smelly lamb when I ate it, meat was tough, not delicious, the smell was strong after cooked
2	13	4	Red	5	4	5	4	4	5	5	appearnce almost good, the smell is small, the smell is important. Overall the meat is very good
2	13	4	Red	6	3	4	3	3	4	3	
2	13	4	Red	7	3	5	4	3	3	3	
2	13	4	Red	8	3	3	2	2	2	1	taste was a little sweet, but very strong smell. When chewing could smell strongly, overall taste was bad
2	13	4	Red	9	3	4	5	5	4	4	

Day	Age	Order	Dot	Booth	Appearance	Colour	Small	Taste	Texture	Overall	Comments
2	13	4	Red	10	4	4	4	5	5	5	less smell than rest of meat, I could eat it without seasoning
2	13	4	Red	11	2	5	5	4	5	4	uneven portion, good coliur, compared to other 3 meats it tasted very strong, meaty flavour, meat was tender and easy to eat
2	13	4	Red	12	2	2	3	2	2	2	uneven portions, didn't look good, coulour was too dark, little tough, strong smell
2	13	4	Red	13	4	4	3	4	5	4	shiny, looks delicious, but white bit was not good, couldn't smell it, couldn't taste blood and aftertaste was very mild, best of 4
2	13	4	Red	14	5	5	4	2	5	4	looks delicious, wasn't sweet but tender, easy to eat
2	31	2	Green	5	5	5	5	5	4	5	the appearance is very good, several pieces are same size the red colour is very beautiful. Good taste for young people, elders find too hard
2	31	2	Green	6	4	4	3	2	3	2	
2	31	2	Green	7	3	5	4	3	3	3	
2	31	2	Green	8	5	4	3	4	4	5	meat was tender and juicy, not very smelly, taste was sweet and delicious. When meat was still raw could smell it slightly, but was good after cooking
2	31	2	Green	9	5	5	5	5	5	5	tender delicious, distinct lamb flavour, but didn't smell strong.
2	31	2	Green	10	4	4	4	3	3	4	meat was a little tough. People who don't like lamb will not like the smell of meat
2	31	2	Green	11	4	5	4	5	4	4	meat was all one coulour so looked good, size was uneven, strong smell, a little tough
2	31	2	Green	12	5	5	5	4	4	4	beautiful pink colour, was nice, smells like raw salmon, I expected a better taste
2	31	2	Green	13	5	5	3	4	4	4	looks fresh, fat was good amount, very shiny, prefer the blue
2	31	2	Green	14	5	5	3	4	5	4	after cooked it had nice smell, when I was chewing and chewing the weetness dissapeared
2	34	3	Yellow	5	5	4	5	5	5	5	pieces good size, colour looked very cheap, not like fresh meat. Taste is very soft and little oil, many people

Day	Age	Order	Dot	Booth	Appearance	Colour	Small	Taste	Texture	Overall	Comments
											like it
2	34	3	Yellow	6	4	3	4	4	4	4	
2	34	3	Yellow	7	3	5	4	2	3	3	
2	34	3	Yellow	8	4	4	2	3	3	2	before it was cooked it smelt very strong, dry texture and could smell. After I ate it could still smell it in my mouth
2	34	3	Yellow	9	4	5	5	5	4	5	when I initially chewed the meat I thought it was tough, however was not overall. Couldn’t smell much and was tender
2	34	3	Yellow	10	3	4	4	3	3	3	didn’t mind the whiteline but other people will, better than other 2 meat, could smell a little however if it had seasoning would prob be okay
2	34	3	Yellow	11	4	5	5	5	5	5	size is bigger than green or blue, this size good as a portion, meat was tender and easy to chew
2	34	3	Yellow	12	5	5	3	4	5	5	shiny beautiful colour, tiny bit tough, but I liked it, later could smell the lamb
2	34	3	Yellow	13	4	4	3	4	4	4	shiny colour, looks good, too much blood, mild and easy to eat, a little tougher than others
2	34	3	Yellow	14	2	2	5	1	4	2	after cooked it smelt nice, taste was not sweet at all, meat was tender but some parts were tough and couldn’t chew, I wouldn’t eat this again
2	35	1	Blue	5	4	4	5	5	5	5	several pieces are small, prefer bigger pieces, overall meat is very good taste and texture for people
2	35	1	Blue	6	2	3	5	4	3	4	
2	35	1	Blue	7	3	5	4	4	4	4	
2	35	1	Blue	8	5	5	3	3	4	3	meat was tender but a strong smell. Colour looks pink and beautiful but not quite smelly
2	35	1	Blue	9	4	5	5	5	4	4	during chewing I could smell typical lamb, the white part was very tough
2	35	1	Blue	10	4	4	4	2	5	2	I could smell very strong lam, if not a fan this would not be edible
2	35	1	Blue	11	5	5	5	5	5	5	size was good, easy to cook, I would definitely buy it, good colour, easy to chew

Day	Age	Order	Dot	Booth	Appearance	Colour	Small	Taste	Texture	Overall	Comments
2	35	1	Blue	12	4	3	4	3	3	3	smell was good, but taste not as good as smell, texture a bit dry
2	35	1	Blue	13	4	4	3	5	4	4	not all the meat was the same colour and some was shinier than others, not very strong smell, taste was mild and easy yo eat
2	35	1	Blue	14	5	5	5	5	5	5	I could taste strong meat after chewing and chewing it tasted better and better. After it was cooked I couldn't smell typical lamb, this was the best meat so far
3	13	4	Red	5	5	5	5	4	5	5	taste is good because of little fat, nice soft meat but after I eat I feel bad smells
3	13	4	Red	6	4	4	3	3	2	3	
3	13	4	Red	7	4	5	3	3	3	3	portion was uneven, looks delicious, bad lamb smell, sour taste, tough
3	13	4	Red	8	3	3	3	3	2	3	
3	13	4	Red	9	4	5	5	5	5	4	was nice at beginning of eating, but after wasn't
3	13	4	Red	10	5	5	4	4	4	4	the colour was good, shiny, no smell, taste nice, easy to taste
3	13	4	Red	11	4	5	5	5	5	5	
3	13	4	Red	12	4	2	3	2	2	2	
3	13	4	Red	13	4	4	3	2	3	3	lots of white, didn't like. Could taste strong blood, too chewy
3	13	4	Red	14	3	3	2	5	4	4	
3	31	3	Green	5	4	4	5	3	3	3	appearance is slightly good, many people feel this pack is not benefit, very fat meat with hard texture, the meat give people very little satisfaction
3	31	3	Green	6	2	3	2	4	5	4	
3	31	3	Green	7	4	5	4	3	2	3	not displayed well, was messy, looks delicious, good smell, but tough
3	31	3	Green	8	4	4	2	3	3	3	
3	31	3	Green	9	4	5	5	5	5	5	could see white bit but meat was tender and nice, smell wasn't too bad
3	31	3	Green	10	4	4	4	3	3	3	very strong smell hard to eat

Day	Age	Order	Dot	Booth	Appearance	Colour	Small	Taste	Texture	Overall	Comments
3	31	3	Green	11	4	5	5	4	5	4	uneven portions, looked messy, couldn't smell it, taste good, meat was tender
3	31	3	Green	12	4	4	4	3	4	4	
3	31	3	Green	13	4	5	3	3	3	3	shiny and fresh, could see blood which I didt like, no smell, could taste blood, chewy
3	31	3	Green	14	5	5	5	5	5	5	
3	34	2	Yellow	5	5	5	5	4	4	4	appearance is beatiful, good smell before cooking, bad smell after, texture and taste a little hard
3	34	2	Yellow	6	4	4	4	4	4	4	
3	34	2	Yellow	7	5	5	4	2	3	3	display wasn't perfect, delicious, good lamb msell, not much taste and was tough
3	34	2	Yellow	8	4	4	3	3	4	3	
3	34	2	Yellow	9	5	5	5	5	4	4	little tough, could smell the lamb while chewing
3	34	2	Yellow	10	4	4	4	4	4	4	
3	34	2	Yellow	11	5	5	4	5	5	5	portion was even, looked really nice, colour good and shiny, no smell
3	34	2	Yellow	12	5	5	5	3	3	4	
3	34	2	Yellow	13	4	4	2	4	3	3	looks fresh and shiny, nice, smells strong, not a bad smell, again a little tough
3	34	2	Yellow	14	5	5	5	4	5	3	
3	35	1	Blue	5	5	5	5	5	5	5	appearance and colour is good, pieces and size are also good, no bad smells, taste very good
3	35	1	Blue	6	2	4	2	3	2	3	
3	35	1	Blue	7	3	5	4	3	3	3	portions uneven, looks delicious, liked the texture but not the white part, taste dissapeared during chewing
3	35	1	Blue	8	3	3	3	5	4	4	
3	35	1	Blue	9	5	5	4	5	4	5	meat was a little tough, but was chewable, liked it
3	35	1	Blue	10	4	4	4	4	3	4	after it was cooked it had a very strong smell
3	35	1	Blue	11	4	5	4	4	5	4	good portion size, colour was good, meat was tender and easy to eat, tasted nice
3	35	1	Blue	12	3	3	4	5	4	4	

Day	Age	Order	Dot	Booth	Appearance	Colour	Small	Taste	Texture	Overall	Comments
3	35	1	Blue	13	3	3	3	4	4	3	could see blood, some meat was too dark, no smell, easy to eat but could taste a little blood
3	35	1	Blue	14	2	2	5	4	4	3	
4	13	1	Red	5	4	5	5	5	5	5	
4	13	1	Red	6	2	3	2	2	1	2	
4	13	1	Red	7	3	5	4	2	2	2	messy presentation, sour taste, had trouble chewing some parts
4	13	1	Red	8	3	3	3	3	3	3	could smell a little lamb, texture was dry and tough, no after smell
4	13	1	Red	9	5	5	3	4	2	3	
4	13	1	Red	10	5	4	3	4	2	4	smell not too strong, meat was dry
4	13	1	Red	11	5	5	5	5	5	5	sizes and portions looked nice, very shiny, colour is good, meat was tender, just right, taste was good
4	13	1	Red	12	5	5	5	3	3	3	the looks very good, smells like salmon, couldn't taste at first, smell of lamb while chewing, texture was dry and not too good
4	13	1	Red	13	3	3	3	3	3	3	
4	13	1	Red	14	3	2	2	5	4	4	
4	31	4	Green	5	4	5	5	3	3	3	
4	31	4	Green	6	4	4	4	3	2	3	
4	31	4	Green	7	4	5	3	3	3	3	could see lots of fat, looks delicious, not good smell, strong sour taste, little dry
4	31	4	Green	8	4	3	2	4	3	4	couldn't smell much, meat was tender and sweet needed more juice, after cooked taste was good
4	31	4	Green	9	5	5	4	3	4	4	
4	31	4	Green	10	4	4	3	5	4	4	this meat was best today
4	31	4	Green	11	4	5	4	3	5	3	colour is very good and shiny, packet looks messy, could taste and smell a little lamb
4	31	4	Green	12	5	4	2	2	2	2	looks good,some meat was pink, smell was not too good
4	31	4	Green	13	4	4	2	4	3	4	

Day	Age	Order	Dot	Booth	Appearance	Colour	Small	Taste	Texture	Overall	Comments
4	31	4	Green	14	4	4	1	1	3	1	could smell this, meat was tender, couldn't taste any sweetness, wouldn't eat again
4	34	2	Yellow	5	5	5	5	4	5	5	
4	34	2	Yellow	6	4	4	1	3	4	3	
4	34	2	Yellow	7	4	5	3	2	2	2	looks tough, can see white lines, looks delicious, not much taste but was sour
4	34	2	Yellow	8	3	3	3	2	2	2	when meat was raw could smell, even after cook could still smell, some parts were tough, taste was not great
4	34	2	Yellow	9	5	5	4	2	5	3	
4	34	2	Yellow	10	5	5	4	4	4	4	
4	34	2	Yellow	11	5	5	5	4	5	4	colour was good and shiny, meat was nice and tender, could smell lamb after eating
4	34	2	Yellow	12	5	5	4	3	4	4	portions were bigger than others, looks better, smell strong but not bad, texture good and taste not too strong
4	34	2	Yellow	13	5	5	3	3	3	4	
4	34	2	Yellow	14	5	5	5	1	1	2	after cooked could smell a little bit, when I was eating couldn't taste any sweetness, texture was not good, took a long time to chew, taste was not good
4	35	3	Blue	5	5	5	5	5	5	5	
4	35	3	Blue	6	1	3	3	4	4	4	
4	35	3	Blue	7	2	2	4	4	3	4	sour taste, but was tasty, little tough but was nice
4	35	3	Blue	8	3	3	4	4	4	4	couldn't smell at all, meat was sweet and juicy and tender
4	35	3	Blue	9	3	3	3	5	5	4	
4	35	3	Blue	10	3	3	5	4	4	4	this meat was much easier to eat than other
4	35	3	Blue	11	4	5	5	5	5	4	too much fat, how samples were cut looked messy, taste was nice but a little to oily
4	35	3	Blue	12	3	3	3	5	5	3	portion sizes uneven, no smell, beautiful taste, texture was good
4	35	3	Blue	13	4	3	3	4	4	4	
4	35	3	Blue	14	1	1	5	3	3	3	meat didn't look fresh, after cook very good aroma,

Day	Age	Order	Dot	Booth	Appearance	Colour	Small	Taste	Texture	Overall	Comments
											some meat was sweet and tender, some was tough and not sweet, too much gristle, hard to chew

9.6 Appendix 6: Statistical Analyses

Microbiological Results

9.6.1.1 Analysis of APC incubated at 25°C

```
> ## Test if there are differences between the two sample types
> anova(aov(log10(apc25) ~ type * age, data=Micro, subset=day==0))
Analysis of Variance Table

Response: log10(apc25)
          Df  Sum Sq Mean Sq F value        Pr(>F)
type       1  0.4056  0.4056  0.9065        0.3505
age        1 31.5533 31.5533 70.5221 0.00000001323
type:age   1  0.0444  0.0444  0.0992        0.7556
Residuals 24 10.7382  0.4474

> ## Fit a linear trend to log APC25 results - allow for different intercepts and
> ## slopes for each proudct age.
> lm1.apc25 <- lm(log10(apc25) ~ factor(age)*hours, data=Micro, subset=type=="slices")
> Anova(lm1.apc25, type="II") ## Different slopes not significant
Anova Table (Type II tests)

Response: log10(apc25)
                  Sum Sq Df  F value Pr(>F)
factor(age)       80.705  3 206.0034 <2e-16
hours             21.066  1 161.3160 <2e-16
factor(age):hours  0.527  3   1.3461 0.2696
Residuals          6.791 52
> lm2.apc25 <- update(lm1.apc25, .~.-factor(age):hours)
> Anova(lm2.apc25, type="II")
Anova Table (Type II tests)

Response: log10(apc25)
            Sum Sq Df F value    Pr(>F)
factor(age) 80.705  3  202.19 < 2.2e-16
hours       21.066  1  158.33 < 2.2e-16
Residuals    7.318 55
> summary(lm2.apc25)

Call:
lm(formula = log10(apc25) ~ factor(age) + hours, data = Micro,
    subset = type == "slices")

Residuals:
     Min       1Q   Median       3Q      Max
-0.62689 -0.20707 -0.07225  0.19529  1.03896

Coefficients:
              Estimate Std. Error t value       Pr(>|t|)
(Intercept)   3.067460   0.131766  23.280         < 2e-16
factor(age)31 1.097099   0.133193   8.237 0.0000000000359
factor(age)34 2.579511   0.133193  19.367         < 2e-16
factor(age)35 2.870181   0.133193  21.549         < 2e-16
hours         0.017595   0.001398  12.583         < 2e-16

Residual standard error: 0.3648 on 55 degrees of freedom
Multiple R-squared: 0.9329,      Adjusted R-squared: 0.928
F-statistic: 191.2 on 4 and 55 DF,  p-value: < 2.2e-16

> plot(lm2.apc25) ## Diagnostic plots look OK

> ## Could Age be included as a linear term?
> lm1.apc25a <- lm(log10(apc25) ~ age*hours, data=Micro, subset=type=="slices")
> anova(lm1.apc25a,lm1.apc25)
Analysis of Variance Table

Model 1: log10(apc25) ~ age * hours
Model 2: log10(apc25) ~ factor(age) * hours
  Res.Df     RSS Df Sum of Sq      F            Pr(>F)
1     56 22.6077
2     52  6.7906  4   15.8171 30.281 0.0000000000005035
```

Analysis of APC incubated at 35℃

```
> ## Test if there are differences between the two sample types
> anova(aov(log10(apc35) ~ type * age, data=Micro, subset=day==0))
Analysis of Variance Table

Response: log10(apc35)
          Df Sum Sq Mean Sq F value        Pr(>F)
type       1  0.165   0.165  0.3172        0.5785
age        1 33.298  33.298 64.0821 0.00000003120
type:age   1  0.179   0.179  0.3451        0.5624
Residuals 24 12.471   0.520

> ## Fit a linear trend to log APC35 results - allow for different intercepts and
> ## slopes for each proudct age.
> lm1.apc35 <- lm(log10(apc35) ~ factor(age)*hours, data=Micro, subset=type=="slices")
> Anova(lm1.apc35, type="II")
Anova Table (Type II tests)

Response: log10(apc35)
                  Sum Sq Df  F value Pr(>F)
factor(age)       82.395  3 181.2131 <2e-16
hours             21.282  1 140.4154 <2e-16
factor(age):hours  0.513  3   1.1278 0.3464
Residuals          7.881 52
> lm2.apc35 <- update(lm1.apc35, .~.-factor(age):hours)
> Anova(lm2.apc35, type="II")
Anova Table (Type II tests)

Response: log10(apc35)
            Sum Sq Df F value    Pr(>F)
factor(age) 82.395  3  179.96 < 2.2e-16
hours       21.282  1  139.44 < 2.2e-16
Residuals    8.394 55
> summary(lm2.apc35)

Call:
lm(formula = log10(apc35) ~ factor(age) + hours, data = Micro,
    subset = type == "slices")

Residuals:
      Min        1Q    Median        3Q       Max
-0.848103 -0.263045 -0.004669  0.192883  1.042363

Coefficients:
              Estimate Std. Error t value        Pr(>|t|)
(Intercept)   2.925545   0.141122  20.731          < 2e-16
factor(age)31 1.217727   0.142650   8.536 0.0000000000118
factor(age)34 2.641441   0.142650  18.517          < 2e-16
factor(age)35 2.918284   0.142650  20.458          < 2e-16
hours         0.017685   0.001498  11.809          < 2e-16

Residual standard error: 0.3907 on 55 degrees of freedom
Multiple R-squared: 0.9251,      Adjusted R-squared: 0.9197
F-statistic: 169.8 on 4 and 55 DF,  p-value: < 2.2e-16

> plot(lm2.apc35)

> ## Could Age be included as a linear term?
> lm1.apc35a <- lm(log10(apc35) ~ age*hours, data=Micro, subset=type=="slices")
> anova(lm1.apc35a,lm1.apc35)
Analysis of Variance Table

Model 1: log10(apc35) ~ age * hours
Model 2: log10(apc35) ~ factor(age) * hours
  Res.Df     RSS Df Sum of Sq     F           Pr(>F)
1     56 21.8551
2     52  7.8812  4   13.9739 23.05 0.00000000005359
```

9.6.1.2 Analysis of LAB incubated at 25℃

```
> ## Test if there are differences between the two sample types
> anova(aov(log10(lab25) ~ type + age, data=Micro, subset=day==0))
Analysis of Variance Table

Response: log10(lab25)
          Df Sum Sq Mean Sq F value        Pr(>F)
```

```
type       1  0.628   0.628  1.2712        0.2703
age        1 33.202  33.202 67.1768 0.00000001507
Residuals 25 12.356   0.494

> ## Fit a linear trend to log LAB25 results - allow for different intercepts and
> ## slopes for each proudct age.
> lm1.lab25 <- lm(log10(lab25) ~ factor(age)*hours, data=Micro, subset=type=="slices")
> Anova(lm1.lab25, type="II") ## Different slopes not significant
Anova Table (Type II tests)

Response: log10(lab25)
                  Sum Sq Df F value             Pr(>F)
factor(age)       72.117  3 92.0739          < 2.2e-16
hours             24.451  1 93.6501 0.0000000000003187
factor(age):hours  1.051  3  1.3422             0.2708
Residuals         13.576 52
> lm2.lab25 <- update(lm1.lab25, .~.-factor(age):hours)
> Anova(lm2.lab25, type="II")
Anova Table (Type II tests)

Response: log10(lab25)
            Sum Sq Df F value             Pr(>F)
factor(age) 72.117  3  90.387          < 2.2e-16
hours       24.451  1  91.934 0.0000000000002462
Residuals   14.628 55
> summary(lm2.lab25)

Call:
lm(formula = log10(lab25) ~ factor(age) + hours, data = Micro,
    subset = type == "slices")

Residuals:
     Min       1Q   Median       3Q      Max
-0.98019 -0.31543 -0.02496  0.19286  1.87379

Coefficients:
              Estimate Std. Error t value          Pr(>|t|)
(Intercept)   2.916214   0.186293  15.654            < 2e-16
factor(age)31 1.137416   0.188311   6.040 0.000000138585012
factor(age)34 2.536484   0.188311  13.470            < 2e-16
factor(age)35 2.675854   0.188311  14.210            < 2e-16
hours         0.018956   0.001977   9.588 0.000000000000246

Residual standard error: 0.5157 on 55 degrees of freedom
Multiple R-squared: 0.8685,     Adjusted R-squared: 0.8589
F-statistic: 90.77 on 4 and 55 DF,  p-value: < 2.2e-16

> plot(lm2.lab25) ## Diagnostic plots look OK

> ## Could Age be included as a linear term? Check the residuals
> lm1.lab25a <- lm(log10(lab25) ~ age*hours, data=Micro, subset=type=="slices")
> anova(lm1.lab25a,lm1.lab25)
Analysis of Variance Table

Model 1: log10(lab25) ~ age * hours
Model 2: log10(lab25) ~ factor(age) * hours
  Res.Df    RSS Df Sum of Sq     F      Pr(>F)
1     56 25.983
2     52 13.576  4    12.407 11.88 0.000000628
```

9.6.1.3 Analysis of LAB incubated at 35℃

```
> ## Test if there are differences between the two sample types
> anova(aov(log10(lab35) ~ type + age, data=Micro, subset=day==0))
Analysis of Variance Table

Response: log10(lab35)
          Df Sum Sq Mean Sq F value    Pr(>F)
type       1 20.204  20.204 13.8837 0.0009976
age        1  4.591   4.591  3.1545 0.0878919
Residuals 25 36.381   1.455

> ## Fit a linear trend to log LAB35 results - allow for different intercepts and
> ## slopes for each proudct age.
> lm1.lab35 <- lm(log10(lab35) ~ factor(age)*hours, data=Micro, subset=type=="slices")
> Anova(lm1.lab35, type="II") ## Different slopes not significant
Anova Table (Type II tests)
```

```
Response: log10(lab35)
                   Sum Sq Df F value          Pr(>F)
factor(age)        46.721  3 14.0501 0.0000007906119
hours              67.632  1 61.0152 0.0000000002533
factor(age):hours   3.596  3  1.0814          0.3651
Residuals          57.639 52
> lm2.lab35 <- update(lm1.lab35, .~.-factor(age):hours)
> Anova(lm2.lab35, type="II")
Anova Table (Type II tests)

Response: log10(lab35)
             Sum Sq Df F value          Pr(>F)
factor(age) 46.721  3  13.988 0.0000006823160
hours       67.632  1  60.745 0.0000000001891
Residuals   61.235 55
> summary(lm2.lab35)

Call:
lm(formula = log10(lab35) ~ factor(age) + hours, data = Micro,
    subset = type == "slices")

Residuals:
    Min      1Q  Median      3Q     Max
-3.2305 -0.3831 -0.1525  0.6104  1.8214

Coefficients:
              Estimate Std. Error t value       Pr(>|t|)
(Intercept)   1.518429   0.381163   3.984       0.000201
factor(age)31 1.001155   0.385290   2.598       0.011996
factor(age)34 1.269856   0.385290   3.296       0.001722
factor(age)35 2.477101   0.385290   6.429 0.000000032351
hours         0.031527   0.004045   7.794 0.000000000189

Residual standard error: 1.055 on 55 degrees of freedom
Multiple R-squared: 0.6513,      Adjusted R-squared: 0.6259
F-statistic: 25.68 on 4 and 55 DF,  p-value: 0.000000000004961

> plot(lm2.lab35) ## Diagnostic plots look OK

> ## Could Age be included as a linear term? Check the residuals
> lm1.lab35a <- lm(log10(lab35) ~ age*hours, data=Micro, subset=type=="slices")
> anova(lm1.lab35a,lm1.lab35)
Analysis of Variance Table

Model 1: log10(lab35) ~ age * hours
Model 2: log10(lab35) ~ factor(age) * hours
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1     56 72.454
2     52 57.639  4    14.815 3.3413 0.0165
```

Sensory Results

9.6.1.4 Analysis of Appearance

```
> ## Fit a model which takes into account a different baseline per panellist
> ## (booth), allows for a trend over days 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 ~ booth + day*order + factor(age), data=Japan)
> Anova(fit.app1, type="II")
Anova Table (Type II tests)

Response: appearance
              Sum Sq  Df F value    Pr(>F)
booth         26.656   9  4.0316 0.0001269
day            0.011   1  0.0153 0.9016875
order          2.817   1  3.8341 0.0521544
factor(age)   12.934   3  5.8685 0.0008275
day:order      1.002   1  1.3638 0.2448080
Residuals    105.789 144
> plot(fit.app1)

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

```
Response: appearance
              Sum Sq  Df F value    Pr(>F)
booth         26.656   9  4.0215 0.0001298
day            0.011   1  0.0153 0.9018088
order          2.817   1  3.8245 0.0524323
factor(age)   13.824   3  6.2568 0.0005045
Residuals    106.791 145
> fit.app3 <- update(fit.app2, .~. - day)
> Anova(fit.app3, type="II")
Anova Table (Type II tests)

Response: appearance
              Sum Sq  Df F value    Pr(>F)
booth         26.656   9  4.0488 0.0001188
order          2.817   1  3.8504 0.0516348
factor(age)   13.824   3  6.2993 0.0004766
Residuals    106.802 146
> summary(fit.app3)

Call:
lm(formula = appearance ~ booth + order + factor(age), data = Japan)

Residuals:
     Min       1Q   Median       3Q      Max
-2.25625 -0.51910  0.05208  0.52396  1.92708

Coefficients:
              Estimate Std. Error t value  Pr(>|t|)
(Intercept)    4.77569    0.34157  13.982   < 2e-16
booth6        -1.12500    0.30239  -3.720  0.000283
booth7        -1.25000    0.30239  -4.134 0.0000599
booth8        -1.00000    0.30239  -3.307  0.001187
booth9        -0.18750    0.30239  -0.620  0.536186
booth10       -0.31250    0.30239  -1.033  0.303111
booth11       -0.50000    0.30239  -1.653  0.100380
booth12       -0.56250    0.30239  -1.860  0.064872
booth13       -0.56250    0.30239  -1.860  0.064872
booth14       -1.06250    0.30239  -3.514  0.000589
order         -0.14444    0.07361  -1.962  0.051635
factor(age)31  0.41389    0.19213   2.154  0.032866
factor(age)34  0.44444    0.21223   2.094  0.037976
factor(age)35 -0.26667    0.22083  -1.208  0.229177

Residual standard error: 0.8553 on 146 degrees of freedom
Multiple R-squared: 0.2861,     Adjusted R-squared: 0.2225
F-statistic:   4.5 on 13 and 146 DF,  p-value: 0.000002023

> plot(fit.app3)

> model.tables(aov(appearance ~ booth + order + factor(age), data=Japan),
+              type="mean")
Tables of means
Grand mean

3.90625

 booth
booth
    5     6     7     8     9    10    11    12    13    14
4.563 3.438 3.313 3.563 4.375 4.250 4.063 4.000 4.000 3.500

 order
order
    1     2     3     4
4.068 3.960 3.853 3.745

 factor(age)
factor(age)
   13    31    34    35
3.731 4.154 4.221 3.519
Warning message:
In replications(paste("~", xx), data = mf) : non-factors ignored: order
```

9.6.1.5 Analysis of Colour

```
> ## Fit a model which takes into account a different baseline per panellist
```

```
> ## (booth), allows for a trend over days 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 ~ booth + day*order + factor(age), data=Japan)
> Anova(fit.col1, type="II")
Anova Table (Type II tests)

Response: colour
            Sum Sq  Df F value          Pr(>F)
booth       42.975   9  8.0011 0.000000001494
day          0.845   1  1.4159      0.2360364
order        3.113   1  5.2162      0.0238403
factor(age) 10.617   3  5.9301      0.0007653
day:order    0.629   1  1.0543      0.3062364
Residuals   85.938 144
> plot(fit.col1)
Waiting to confirm page change...
Waiting to confirm page change...
Waiting to confirm page change...
Waiting to confirm page change...
> fit.col2 <- update(fit.col1, .~. - day:order)
> Anova(fit.col2, type="II")
Anova Table (Type II tests)

Response: colour
            Sum Sq  Df F value          Pr(>F)
booth       42.975   9  7.9981 0.000000001464
day          0.845   1  1.4154      0.2361102
order        3.113   1  5.2142      0.0238559
factor(age) 11.213   3  6.2606      0.0005021
Residuals   86.567 145
> fit.col3 <- update(fit.col2, .~. - day)
> Anova(fit.col3, type="II")
Anova Table (Type II tests)

Response: colour
            Sum Sq  Df F value          Pr(>F)
booth       42.975   9  7.9754 0.000000001514
order        3.113   1  5.1994      0.0240424
factor(age) 11.213   3  6.2428      0.0005119
Residuals   87.412 146
> summary(fit.col3)

Call:
lm(formula = colour ~ booth + order + factor(age), data = Japan)

Residuals:
     Min       1Q   Median       3Q      Max
-2.34769 -0.36424 -0.01157  0.52639  1.96389

Coefficients:
              Estimate Std. Error t value   Pr(>|t|)
(Intercept)     4.9560     0.3090  16.038    < 2e-16
booth6         -0.8750     0.2736  -3.198   0.001694
booth7          0.1250     0.2736   0.457   0.648403
booth8         -1.0000     0.2736  -3.655   0.000358
booth9          0.0625     0.2736   0.228   0.819606
booth10        -0.5000     0.2736  -1.828   0.069636
booth11         0.1875     0.2736   0.685   0.494185
booth12        -0.9375     0.2736  -3.427   0.000793
booth13        -0.6250     0.2736  -2.285   0.023776
booth14        -1.3125     0.2736  -4.798 0.00000392
order          -0.1519     0.0666  -2.280   0.024042
factor(age)31   0.4120     0.1738   2.371   0.019070
factor(age)34   0.3102     0.1920   1.616   0.108357
factor(age)35  -0.2778     0.1998  -1.390   0.166529

Residual standard error: 0.7738 on 146 degrees of freedom
Multiple R-squared: 0.3913,     Adjusted R-squared: 0.3371
F-statistic: 7.219 on 13 and 146 DF,  p-value: 0.0000000009241

> plot(fit.col3)

> model.tables(aov(colour ~ booth + order + factor(age), data=Japan),
+              type="mean")
Tables of means
Grand mean
```

```
4.2

 booth
booth
    5     6     7     8     9    10    11    12    13    14
4.688 3.813 4.812 3.688 4.750 4.188 4.875 3.750 4.062 3.375

 order
order
   1    2    3    4
4.35 4.25 4.15 4.05

 factor(age)
factor(age)
   13    31    34    35
4.050 4.475 4.425 3.850
Warning message:
In replications(paste("~", xx), data = mf) : non-factors ignored: order
```

9.6.1.6 Analysis of Smell

```
> ## Fit a model which takes into account a different baseline per panellist
> ## (booth), allows for a trend over days 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 ~ booth + day*order + factor(age), data=Japan)
> Anova(fit.smell1, type="II")
Anova Table (Type II tests)

Response: smell
            Sum Sq  Df F value              Pr(>F)
booth       70.525   9 12.5548 0.00000000000001404
day          4.805   1  7.6984             0.00626
order        0.267   1  0.4272             0.51439
factor(age)  2.547   3  1.3602             0.25742
day:order    0.475   1  0.7614             0.38435
Residuals   89.878 144
> plot(fit.smell1)

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

Response: smell
            Sum Sq  Df F value              Pr(>F)
booth       70.525   9 12.5755 0.00000000000001259
day          4.805   1  7.7111            0.006214
order        0.267   1  0.4279            0.514033
factor(age)  2.072   3  1.1082            0.347869
Residuals   90.353 145

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

Response: smell
            Sum Sq  Df F value              Pr(>F)
booth       70.525   9 12.6249 0.00000000000001055
day          4.805   1  7.7414             0.00611
factor(age)  4.450   3  2.3898             0.07117
Residuals   90.620 146
> summary(fit.smell3)

Call:
lm(formula = smell ~ booth + day + factor(age), data = Japan)

Residuals:
     Min       1Q   Median       3Q      Max
-2.64250 -0.39500  0.03125  0.48563  1.80750

Coefficients:
               Estimate Std. Error t value          Pr(>|t|)
(Intercept)     5.12500    0.26425  19.395           < 2e-16
booth6         -1.81250    0.27854  -6.507 0.00000000114834
booth7         -0.93750    0.27854  -3.366          0.000976
booth8         -1.93750    0.27854  -6.956 0.00000000010916
```

```
booth9        -0.87500    0.27854  -3.141         0.002036
booth10       -0.81250    0.27854  -2.917         0.004093
booth11       -0.18750    0.27854  -0.673         0.501917
booth12       -1.31250    0.27854  -4.712 0.00000566282679
booth13       -2.06250    0.27854  -7.405 0.00000000000966
booth14       -0.93750    0.27854  -3.366         0.000976
day           -0.15500    0.05571  -2.782         0.006110
factor(age)31  0.07500    0.17617   0.426         0.670927
factor(age)34  0.32500    0.17617   1.845         0.067085
factor(age)35  0.40000    0.17617   2.271         0.024635

Residual standard error: 0.7878 on 146 degrees of freedom
Multiple R-squared: 0.4682,      Adjusted R-squared: 0.4208
F-statistic: 9.887 on 13 and 146 DF,  p-value: 0.00000000000001252

> plot(fit.smell3)

> ## Now obtain the means for each factor
> model.tables(aov(smell ~ booth + day + factor(age), data=Japan),
+              type="mean")
Tables of means
Grand mean

3.85

 booth
booth
    5     6     7     8     9    10    11    12    13    14
4.938 3.125 4.000 3.000 4.062 4.125 4.750 3.625 2.875 4.000

 day
day
    1     2     3     4
4.083 3.928 3.772 3.617

 factor(age)
factor(age)
   13    31    34    35
3.650 3.725 3.975 4.050
Warning message:
In replications(paste("~", xx), data = mf) : non-factors ignored: day
```

9.6.1.7 Analysis of Taste

```
> ## Fit a model which takes into account a different baseline per panellist
> ## (booth), allows for a trend over days 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 ~ booth + day*order + factor(age), data=Japan)
> Anova(fit.taste1, type="II")
Anova Table (Type II tests)

Response: taste
             Sum Sq  Df F value     Pr(>F)
booth        38.725   9  4.8058 0.00001297
day           6.125   1  6.8411   0.009858
order         0.856   1  0.9561   0.329812
factor(age)   6.254   3  2.3283   0.077026
day:order     0.017   1  0.0188   0.891054
Residuals   128.927 144
> plot(fit.taste1)

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

Response: taste
             Sum Sq  Df F value     Pr(>F)
booth        38.725   9  4.8386 0.00001165
day           6.125   1  6.8877   0.009609
order         0.856   1  0.9626   0.328165
factor(age)   6.301   3  2.3619   0.073782
Residuals   128.944 145
> fit.taste3 <- update(fit.taste2, .~. - order)
> Anova(fit.taste3, type="II")
Anova Table (Type II tests)
```

```
Response: taste
              Sum Sq  Df F value     Pr(>F)
booth         38.725   9  4.8398 0.00001149
day            6.125   1  6.8894   0.009593
factor(age)    8.325   3  3.1213   0.027904
Residuals    129.800 146
> summary(fit.taste3)

Call:
lm(formula = taste ~ booth + day + factor(age), data = Japan)

Residuals:
    Min      1Q  Median      3Q     Max
-2.7750 -0.5031  0.0875  0.6000  2.0250

Coefficients:
                Estimate Std. Error  t value Pr(>|t|)
(Intercept)    4.737e+00  3.163e-01   14.980  < 2e-16
booth6        -1.312e+00  3.334e-01   -3.937 0.000127
booth7        -1.312e+00  3.334e-01   -3.937 0.000127
booth8        -9.375e-01  3.334e-01   -2.812 0.005597
booth9         9.251e-18  3.334e-01 2.78e-17 1.000000
booth10       -5.000e-01  3.334e-01   -1.500 0.135807
booth11       -6.250e-02  3.334e-01   -0.187 0.851542
booth12       -9.375e-01  3.334e-01   -2.812 0.005597
booth13       -6.250e-01  3.334e-01   -1.875 0.062812
booth14       -1.062e+00  3.334e-01   -3.187 0.001757
day           -1.750e-01  6.667e-02   -2.625 0.009593
factor(age)31  7.500e-02  2.108e-01    0.356 0.722559
factor(age)34 -5.000e-02  2.108e-01   -0.237 0.812872
factor(age)35  5.250e-01  2.108e-01    2.490 0.013892

Residual standard error: 0.9429 on 146 degrees of freedom
Multiple R-squared: 0.2906,      Adjusted R-squared: 0.2274
F-statistic: 4.601 on 13 and 146 DF,  p-value: 0.000001376

> plot(fit.taste3)

> model.tables(aov(taste ~ booth + day + factor(age), data=Japan),
+              type="mean")
Tables of means
Grand mean

3.7625

 booth
booth
    5     6     7     8     9    10    11    12    13    14
4.438 3.125 3.125 3.500 4.438 3.937 4.375 3.500 3.812 3.375

 day
day
    1     2     3     4
4.025 3.850 3.675 3.500

 factor(age)
factor(age)
   13    31    34    35
3.625 3.700 3.575 4.150
Warning message:
In replications(paste("~", xx), data = mf) : non-factors ignored: day
```

9.6.1.8 Analysis of Texture

```
> ## Fit a model which takes into account a different baseline per panellist
> ## (booth), allows for a trend over days and the order of tasting (and their
> ## interaction), and finally allows for different aged meat (different animals)
> ## to have different average scores.
> fit.text1 <- lm(texture ~ booth + day*order + factor(age), data=Japan)
> Anova(fit.text1, type="II")
Anova Table (Type II tests)

Response: texture
              Sum Sq  Df F value         Pr(>F)
booth         54.681   9  7.5521 0.000000005109
day            6.301   1  7.8324       0.005835
order          1.452   1  1.8046       0.181265
```

```
factor(age)   4.061   3  1.6825       0.173401
day:order     0.242   1  0.3004       0.584493
Residuals   115.849 144
> plot(fit.text1)

> fit.text2 <- update(fit.text1, .~. - day:order)
> Anova(fit.text2, type="II")
Anova Table (Type II tests)

Response: texture
             Sum Sq  Df F value       Pr(>F)
booth        54.681   9  7.5887 0.0000000045
day           6.301   1  7.8704     0.005715
order         1.452   1  1.8134     0.180202
factor(age)   3.909   3  1.6276     0.185547
Residuals   116.091 145
> fit.text3 <- update(fit.text2, .~. - factor(age))
> Anova(fit.text3, type="II")
Anova Table (Type II tests)

Response: texture
           Sum Sq  Df F value         Pr(>F)
booth      54.681   9  7.4934 0.000000005435
day         6.301   1  7.7715       0.006005
order       0.011   1  0.0139       0.906392
Residuals 120.000 148
> fit.text4 <- update(fit.text3, .~. - order)
> Anova(fit.text4, type="II")
Anova Table (Type II tests)

Response: texture
           Sum Sq  Df F value         Pr(>F)
booth      54.681   9  7.5433 0.000000004615
day         6.301   1  7.8233       0.005839
Residuals 120.011 149
> summary(fit.text4)

Call:
lm(formula = texture ~ booth + day, data = Japan)

Residuals:
    Min      1Q  Median      3Q     Max
-2.9537 -0.5369  0.1712  0.6637  2.1512

Coefficients:
            Estimate Std. Error t value    Pr(>|t|)
(Intercept)  5.00625    0.27479  18.218     < 2e-16
booth6      -1.62500    0.31730  -5.121 0.000000925
booth7      -1.62500    0.31730  -5.121 0.000000925
booth8      -1.18750    0.31730  -3.742    0.000260
booth9      -0.31250    0.31730  -0.985    0.326286
booth10     -0.56250    0.31730  -1.773    0.078312
booth11      0.12500    0.31730   0.394    0.694184
booth12     -1.00000    0.31730  -3.152    0.001964
booth13     -0.87500    0.31730  -2.758    0.006551
booth14     -0.50000    0.31730  -1.576    0.117196
day         -0.17750    0.06346  -2.797    0.005839

Residual standard error: 0.8975 on 149 degrees of freedom
Multiple R-squared: 0.3369,     Adjusted R-squared: 0.2924
F-statistic: 7.571 on 10 and 149 DF,  p-value: 0.000000001067

> plot(fit.text4)

> ## Now obtain the means for each factor
> model.tables(aov(texture ~ booth + day, data=Japan),
+              type="mean")
Tables of means
Grand mean

3.80625

 booth
booth
    5     6     7     8     9    10    11    12    13    14
4.563 2.938 2.938 3.375 4.250 4.000 4.688 3.563 3.688 4.062
```

```
 day
day
    1     2     3     4 
4.073 3.895 3.718 3.540 
Warning message:
In replications(paste("~", xx), data = mf) : non-factors ignored: day
```

9.6.1.9 Analysis of Overall Score

```
> ## Fit a model which takes into account a different baseline per panellist
> ## (booth), allows for a trend over days and the order of tasting (and their
> ## interaction), and finally allows for different aged meat (different animals)
> ## to have different average scores.
> fit.all1 <- lm(overall ~ booth + day*order + factor(age), data=Japan)
> Anova(fit.all1, type="II")
Anova Table (Type II tests)

Response: overall
             Sum Sq  Df F value      Pr(>F)
booth        34.756   9  4.8950 0.000009984
day           4.651   1  5.8957     0.01641
order         0.389   1  0.4935     0.48349
factor(age)   0.344   3  0.1453     0.93255
day:order     0.073   1  0.0929     0.76099
Residuals   113.605 144                    
> plot(fit.all1)

> fit.all2 <- update(fit.all1, .~. - factor(age))
> Anova(fit.all2, type="II")
Anova Table (Type II tests)

Response: overall
           Sum Sq  Df F value      Pr(>F)
booth      34.756   9  4.9819 0.000007475
day         4.651   1  6.0004     0.01548
order       1.531   1  1.9754     0.16199
day:order   0.306   1  0.3951     0.53062
Residuals 113.949 147                    
> fit.all3 <- update(fit.all2, .~. - day:order)
> Anova(fit.all3, type="II")
Anova Table (Type II tests)

Response: overall
           Sum Sq  Df F value      Pr(>F)
booth      34.756   9  5.0024 0.000006959
day         4.651   1  6.0250     0.01526
order       1.531   1  1.9835     0.16112
Residuals 114.255 148                    
> fit.all4 <- update(fit.all3, .~. - order)
> Anova(fit.all4, type="II")
Anova Table (Type II tests)

Response: overall
           Sum Sq  Df F value      Pr(>F)
booth      34.756   9  4.9696 0.000007581
day         4.651   1  5.9855     0.01559
Residuals 115.786 149                    
> summary(fit.all4)

Call:
lm(formula = overall ~ booth + day, data = Japan)

Residuals:
     Min       1Q   Median       3Q      Max 
-2.54125 -0.41625  0.04125  0.61125  1.76375 

Coefficients:
            Estimate Std. Error t value   Pr(>|t|)
(Intercept)  4.94375    0.26991  18.316    < 2e-16
booth6      -1.50000    0.31167  -4.813 0.00000361
booth7      -1.25000    0.31167  -4.011 0.00009546
booth8      -1.25000    0.31167  -4.011 0.00009546
booth9      -0.37500    0.31167  -1.203   0.230804
booth10     -0.62500    0.31167  -2.005   0.046737
booth11     -0.37500    0.31167  -1.203   0.230804
booth12     -1.06250    0.31167  -3.409   0.000839
booth13     -0.87500    0.31167  -2.807   0.005662
```

```
booth14     -1.25000    0.31167  -4.011 0.00009546
day         -0.15250    0.06233  -2.447   0.015588

Residual standard error: 0.8815 on 149 degrees of freedom
Multiple R-squared: 0.2539,      Adjusted R-squared: 0.2039
F-statistic: 5.071 on 10 and 149 DF,  p-value: 0.000002381

> plot(fit.all4)

> ## Now obtain the means for each factor
> model.tables(aov(overall ~ booth + day, data=Japan),
+              type="mean")
Tables of means
Grand mean

3.70625

 booth
booth
    5     6     7     8     9    10    11    12    13    14
4.562 3.062 3.312 3.312 4.188 3.938 4.188 3.500 3.688 3.312

 day
day
    1     2     3     4
3.935 3.782 3.630 3.478
Warning message:
In replications(paste("~", xx), data = mf) : non-factors ignored: day
```