  

MEAT EATING QUALITY – A WHOLE CHAIN APPROACH

Factors Affecting Lamb Eating Quality

Final Report to SEERAD

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SAC · University of BRISTOL · BioSS · sfqc scottish · UNIVERSITY OF NEWCASTLE UPON TYNE

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In collaboration with:
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MEAT EATING QUALITY – A WHOLE CHAIN APPROACH

EXECUTIVE SUMMARY

The overall aim of this trial was to test whether a package of measures applied on commercial farms and abattoirs produced noticeably better meat eating quality. In particular, the trial looked at whether eating quality was affected when carcass weights were increased without increasing fatness. Participating farms selected wether lambs at weaning that were above average in terms of weight and leanness. These lambs were finished on a planned system that avoided growth checks in the final period. At slaughter, **enhanced lambs** were selected that were in a target carcass weight range of 16-21 kg for Blackfaces and 21-26 kg for crossbreds, and were at a target fat class of 3L. Carcasses from other flocks sent to the abattoir on the same day, which were generally lighter, were chosen as **basal samples**. At the abattoir, the carcasses from both enhanced and basal groups were subjected to either an **enhanced** or a **basal abattoir procedure**. Basal samples were allowed to progress straight to the chiller without any post-slaughter interventions. Enhanced processed samples were electrically stimulated (either low or high voltage, depending on the abattoir). At boning, the left carcass side loins were cut, vacuum packed and conditioned for five days; the right side loins were cut, vacuum packed and conditioned for ten days. Twenty-two farms and three abattoirs took part. A trained **sensory panel** at Bristol tested all the meat samples.

Key findings are:

- It is possible to select heavier carcasses (>16 kg for Blackface and >23 kg for crossbreds) with acceptable fatness (3L) without deleteriously affecting texture or flavour, the main components of eating quality. There was a suggestion that this meat may be less juicy and this needs further investigation.

- A significant proportion of carcasses failed to meet target fat class, suggesting substantial scope to improve selection of lambs for slaughter.

- It is well known from other studies that low growth rates, growth checks and stressful handling of animals, can negatively affect meat quality. In this study, enhanced pre-slaughter protocols had little effect on sensory attributes compared to those of the basal sample. Apart from the weight of lambs they submitted, basal farms were not deliberately chosen to have contrasting management practices to enhanced farms. Basal farms were intended to reflect typical throughput for that abattoir, at that time. The fact that no significant effect of the pre-slaughter enhanced protocol was detected here may be due to good practice in the basal farms supplying the participating abattoirs. Hence, care must be taken to adhere strictly to ‘best practice’ guidelines, and to avoid factors known to negatively affect meat quality.

- Post-slaughter enhanced processing and conditioning had a major, positive impact on the average level of most attributes of lamb eating quality and improved consistency in texture.

- The improvement in eating quality due to post-slaughter enhancement occurred across all breeds, abattoirs and pre-slaughter treatments.

- Electrical stimulation had a much greater impact in improving meat texture than the length of time meat was conditioned.

- Seasonal effects were minor and whilst texture did not deteriorate, the trained sensory panel did detect an increased abnormal flavour in late season lamb. This was significantly higher in crossbred than Blackface lambs. There was no clear evidence from this project that an increase in abnormal flavour over the season was caused by a specific diet. This problem needs to be investigated further with a specifically designed experiment.

- The enhanced processing protocol was particularly effective in controlling consistency in texture, but less so for consistency of other meat quality measures. Season accounted for a high proportion of variation in abnormal flavours. Substantial proportions of variation in all meat quality measures are attributable to individual animal. The precise cause of this variation remains poorly understood, but it is highly likely to include genetic variation within breed. A low to moderate proportion of the variation in texture (11%), juiciness (52%), lamb flavour (40%) and abnormal flavour (31%) could not be explained by any of the factors measured in this trial. The more detailed results presented in the report are useful in highlighting areas where we need a better understanding to control variability in meat eating quality.

BACKGROUND

A pilot study to gather information on current practices for the production and supply of red meat in Scotland, and to identify potential enhanced practices, was carried out by MLC and QMS in 2002. This study involved discussions with industry and consumers, and a review of the scientific literature to provide descriptions of the current and enhanced practices to consistently deliver meat that will satisfy consumer demands for quality and eating experience.

Lamb quality issues identified in the MLC/QMS review included:

- Over-fatness.
- Small size of chops relative to pork.
- High costs of processing for added value due to small carcass size.
- Deteriorating quality in old season's lambs after New Year.

The review suggests that the future for lamb is in the convenience sector as ready meals rather than as roasting joints. However, chops are still seen as convenient as they are very quick to cook.

Eating quality of lamb is not a major problem in general. There is, however, increased toughness and stronger flavour (not disliked by some consumers) with hoggets, over 9 months of age, sold after December. These characteristics are likely to be accentuated following a prolonged store period or severe weaning check and/or by management techniques which are sometimes used to increase carcass weight of genetically small animals. The MLC/QMS review of meat eating quality for lamb began with the statement 'lamb is generally perceived to be of good eating quality' but the main criticism is for its perceived fatness, and lamb fat is disliked for its high melting point and hence sticky mouth feel. There are quality issues in relation to over-fatness at all times of the year caused by farmers not selecting regularly/accurately, and insufficient premiums for leanness. In addition, further issues in relation to eating quality (e.g. flavour/tenderness/juiciness) may arise from poor planning of the finish, dietary changes during the finishing period and imbalance in the protein:energy content of the diet.

Maximum market prices are paid for carcasses meeting fatness and conformation targets in the weight range of 16-21 kg. Consumer needs for larger chops and leaner lamb are currently converging with farmer and processor needs for heavier, leaner lambs (more saleable product for the farmer, lower processing cost for the abattoir), but conflicting with the processors currently imposing price penalties on heavier carcasses through fear of over fat carcasses or concerns over the impact of larger cuts on retail price.

It is likely that high genetic merit lowland genotypes kept on systems involving management without severe checks to growth or major store periods, and fed diets adequate in protein, can easily be taken to weights between 21 kg and 25 kg at fat class 3L. Recent evidence from the Blackface sire reference group indicates that meeting the 16 kg minimum at fat class 3L is attainable for the majority of lambs of this breed by using sires selected for lean growth rate. Many abattoirs currently impose carcass weight restrictions because farmers are not accurately selecting larger lean lambs, use inadequate diets to meet growth requirements and are not fully exploiting the genetic progress that is being made in the industry.

Some of the key practices known to improve lamb eating quality are shown in Table 1. Many producers and processors already use some of these 'best practices'. The purpose of this trial was to test whether the adoption of several key enhanced on–farm and in-abattoir practices led to improved eating quality throughout the lamb production season, especially for heavier, lean carcasses. This work was undertaken within the lamb component of an overarching research project on the improvement of eating quality in the Scottish red meat sector.

Table 1. Some practices that are believed to improve meat eating quality

On farm/pre-slaughter	Post slaughter
Avoiding growth checks Feeding and management to achieve reasonable growth rates Finished on a planned system appropriate to the growth potential of the lamb (set by breed) and current liveweight and condition Avoiding slaughter soon after diet changes Careful selection to meet specification on carcass weight, fatness and conformation	Electrical stimulation of carcasses Aitch-bone hanging of carcasses Considerate chilling of carcasses Conditioning of meat Selection on conformation, fatness, rate of pH fall and ultimate pH

When sheep carcasses are chilled rapidly they will toughen due to cold shortening. This phenomenon was first identified in New Zealand when more efficient chillers and freezers were installed in plants in order to meet the growing demand for export of frozen lamb to the UK. The simplest way to avoid cold shortening is to ensure that the carcass does not cool below 10°C before the muscles have gone into rigor. As a rule of thumb this has been taken as ‘not below 10°C in 10 hours’ from slaughter. This is inconvenient in rapid throughput plants and may be difficult to achieve in winter when the ambient air temperature is low. Small lamb carcasses will still cool rapidly. The New Zealand solution was the invention of High Voltage Electrical Stimulation (HVES) and the protocol for lamb export to UK using HVES has been in place since 1973. Other developments include the use of Low Voltage Electrical Stimulation (LVES) and Hip Suspension. All are designed to reduce muscle shortening and HVES, in particular, may have other tenderising effects. Hip suspension holds commercially important muscles in a stretched position, again preventing cold shortening. These procedures allow more rapid chilling and, hence, more hygienic production and reduced conditioning times.

There is an apparent worry in the industry that producing larger lean carcasses in wintertime will lead to tougher animals due to too rapid chilling. The treatments tested avoided this.

In the last 5-6 years there has been a rapid uptake of HVES in plants supplying two of the top four retailers. Another retailer insists on the combination of LVES and hip suspension. All these procedures have been tested in previous research.

It is clear that many plants do not like hip suspension as it is labour intensive, carcasses require more space and butchers must be retrained to cope with the differently shaped cuts. Hip suspension was not tested, as it was likely that no more than a specialist minority of the industry would take this up.

With three abattoirs taking part in these trials (ABP Bathgate, Kepak Buchan and McIntosh Donald) we had the opportunity to test LVES or HVES, with two levels of conditioning, as enhanced procedures.

OBJECTIVES AND EXPERIMENTAL DESIGN

The overall aim of the trial was to test whether a package of measures, expected to improve eating quality, and applied on farms and in abattoirs, noticeably improved meat eating quality. In particular, the trial looked at whether eating quality was affected when carcass weights were increased without increasing fatness. Participating farms and abattoirs adopted agreed enhanced practices, some of which they do not already use.

The packages were tested by:

1. Targeting the problem of lamb over-fatness at heavier weights during the post-weaning finishing period (September-March) by identifying farms ideally using improved genetics and separating the heavier leaner wether lambs at weaning for planned finishing without severe growth checks**.** The aim of the on-farm part of the trial was to test how easy it was to increase the supply of lean lamb within the current retail weight range of 16-21 kg from Blackface hill flocks and in a higher range still, 21-26 kg, from lowland crossbred flocks.

2. Implementing on-farm monitoring of management and diets fed, to test our ability to produce these heavier lean lambs consistently. Candidate farms were identified to supply heavier, leaner carcasses from weaned lambs, by both genetic and management means.

3. Testing the enhanced procedures of electrical stimulation and conditioning time, within the participating abattoirs, for both heavy and conventional lambs.

4. Testing the resultant samples through a trained sensory panel.

5. Obtaining a better understanding of the interactions between pre- and post-slaughter factors affecting eating quality.

A feature of the comparison was that the on-farm and in-abattoir (post slaughter) components of eating quality in the package were identified separately by using lambs within each farm protocol group on the same day of slaughter and treating one with enhanced abattoir treatment and another with baseline treatment. In addition, the trial design allowed the independent assessment of the effects of conditioning by splitting carcasses from all combinations of pre- and post-slaughter treatments and conditioning one side for five days and the other for ten days.

METHODS

On-farm and transport

Enhanced farm protocol
The design of the protocols to apply on-farm/in-transport was:

- Based on the MLC/QMS review identifying best practices.
- Realistic and achievable in practice by the average farmer with back-up from a trained assessor.
- Not so prescriptive as to create a supply problem for lamb in Scotland.

Twenty-two farms provided lambs to the enhanced protocol (two farms per kill with duplicate animals), ten to plant 1, five to plant 2 and seven to plant 3. The farms were targeted to have a finishing date to be in either September 2003, November 2003, January 2004 or March 2004 (each farm targeted one kill date). Thus, the full range of later season Scottish kill dates was represented with spring lamb deliberately excluded, as it was not thought to be a problem.

Key points in the enhanced protocols were as follows:

- Only wethers of above average weight at weaning were included
- Either hill Blackface or lowland crossbred lambs were included
- Lambs were suckled for at least 3 months, then weaned according to a protocol to reduce stress
- Lambs were finished on the farms' conventional finishing system
- There was a planned finish – lambs were not subjected to a period of weight loss and were fed diets checked for adequacy of protein and energy content in the finishing period.

Participating farmers were sent information around weaning time about how their stock could comply with the enhanced protocol. In order to obtain heavier lambs, without employing severe checks to growth, farmers were advised on procedures at weaning to mitigate against the combined stresses of weaning/handling/dosing and pasture change that often severely check lamb growth at this critical time (see Appendix 1 for details).

There was an initial farm visit by a trials officer at weaning time, when lambs were weighed and the enhanced group identified. Sufficient lambs were identified to enable the farmer to provide 12 to 20 lambs at the target slaughter date. At this initial visit, lambs were identified by a tag in their right ear, showing flock number and individual number, though on some farms this was postponed until the second visit to lessen the risk of fly strike. The lambs were targeted to finish on the farmers' normal system provided that this did not involve store periods (maintenance levels of feeding) of more than two months, or severe growth checks. This was checked by a second visit, for farmers with lambs killed from November onwards, at least 40 days pre-slaughter, when lambs were reweighed. At this visit information on diets fed during the post-weaning finishing phase were collected and, where silage was fed, it was sampled and analysed for nutrient content. Recommendations were made by an SAC nutritionist for changes in supplementary feeding to ensure diets were adequate in protein/energy.

Where necessary, training or assistance was offered in selecting lambs for the level of finish required (fat class 3L).

The farmer completed a checklist of procedures on despatch of animals for slaughter, the purpose of which was to ensure that sheep left the farm and arrived at the abattoir unstressed and in a clean condition. The checklist accompanied the sheep to the abattoir and included confirmation that:

- Haulier had been advised of stock number, collection point, agreed date/time
- Stock had not been physically exercised to exhaustion in the previous 24 hours
- Stock had been off feed for a minimum of 2 hours

- Stock were clean or clipped 2-3d before slaughter
- Electric goads, sticks, alkathane pipes or other blunt hard objects were not used to move stock
- Groups of sheep were not mixed
- Time sheep started loading was recorded (use 24 hr clock)
- Time lorry departed was recorded
- Once loaded, stock moved without delay to abattoir
- SSSFA approved hauliers with all stockpersons/drivers to be properly trained and managed

Basal farm protocol
The basal sample was structured, in so far as animal supply on the day allowed, to reflect the throughput of the participating abattoirs in terms of gender, breed and production system. However, for logistical reasons, in many situations the sampling team had to take what was available. Overall however, there was sufficient representation within the baseline samples to be able to match the enhanced farm samples in terms of grade and conformation and to maintain a weight differential between the two groups.

Slaughter and carcass processing

Carcasses selected to meet specific thresholds from enhanced farm protocol groups, and basal farm carcasses selected at random, were treated with an enhanced abattoir protocol including longer conditioning time (enhanced processing). These were compared with enhanced and basal farm carcasses given no enhanced treatment and only minimum conditioning (basal processing).

Slaughter and carcass processing procedures within abattoirs
At the abattoir the lambs were received by consortia staff and the following recorded:

- Farmer supplier
- No. of animals
- Name of transporter
- Distance to abattoir
- Time of departure
- Time of arrival
- Time unloaded
- Outside weather conditions
- Ambient temperature (measured in the shade outside the lairage)
- Lairage temperature

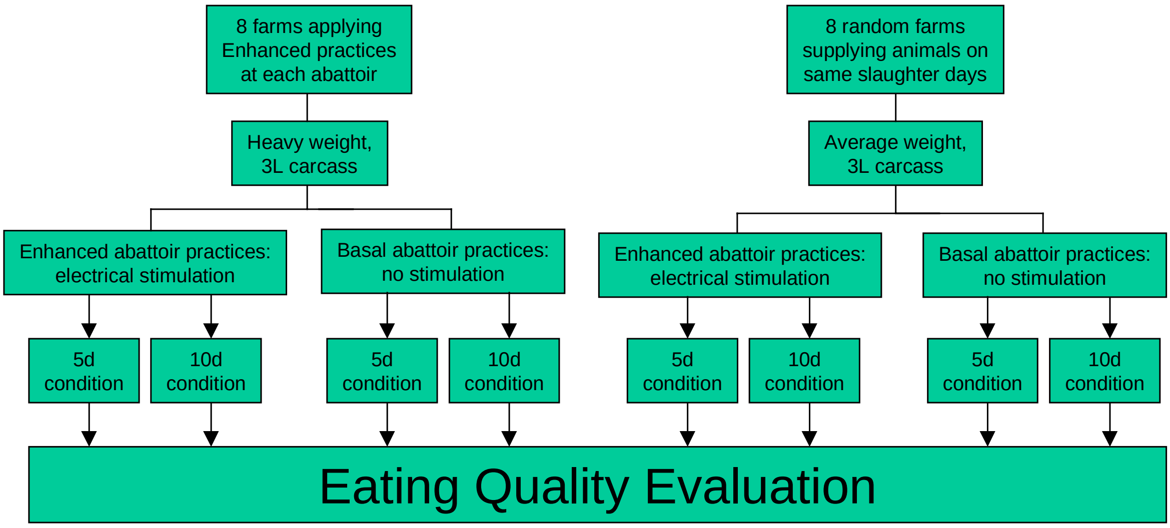
Lambs were allowed to rest for one hour and then moved forward for slaughter with minimum disturbance. Lambs were electrically stunned and killed by exsanguination in all plants. The post-slaughter treatments and the breed types that were slaughtered at each participating abattoir are shown in Table 2.

Table 2. Enhancement and conditioning regimes, breed and month of kill of lambs slaughtered in each abattoir

Abattoir	Enhanced processing regime	Breed and month of kill (% of farms)	
		Blackface (hill)	Crossbred (lowland)
Plant 1	LVES 5 and 10d conditioning	Jan & Mar (50%)	Sept & Nov (50%)
Plant 2	LVES 5 and 10d conditioning	Jan & Mar (50%)	Sept & Nov (50%)
Plant 3	HVES 5 and 10d conditioning	-	Sept to Mar (100%)

The distribution of lambs by breed and month of kill reflect the supply pattern to each abattoir. We hoped to demonstrate whether LVES was as good as HVES and whether the same result is obtained for all production systems, with the proviso that there is no direct comparison within abattoir. In addition, by using two conditioning times we aimed to investigate whether HVES and/or LVES could shorten the conditioning time required to achieve good eating quality and thus save on chiller space for the abattoirs.

Figure 1. Design of post-slaughter processing



The rationale behind the conditioning times chosen was as follows. The minimum time period from slaughter to eating is about three to four days (e.g. kill +1 day = bone and pack; kill + 2-3 days = distribute and bought; kill + 3-4 days = minimum time at consumption). The packs will have around 7 days display life, so cuts would be eaten between 3 and 10 days from the kill date. The MLC Blueprint recommends a minimum of 7 days maturation for HVES treated carcasses, with a small benefit from a further 3 days maturation. Hence, 5 and 10d would be approximately the minimum and maximum times between which a consumer might eat the product.

In all three abattoirs, non-ES samples with short conditioning time acted as common controls.

Enhanced procedures vs. baseline in abattoir

At the abattoir a filter was used to identify the largest, leanest carcasses which went forward for taste panel analyses (four lambs pre-selected per enhanced farm). A retrospective analysis of how close the remainder came to meeting the heavy but lean specification was made. This is a similar protocol to that developed for the pig work where we looked for a 20% increase in carcass weight.

Basal lambs were sourced in the abattoir from other flocks sent in on the same kill day, to minimise any variation caused in eating quality by day of kill effects.

Carcass sampling

Within each of three meat plants, eight selected farms provided up to 20 heavy lean lambs, of which four were filtered off on the basis of carcass weight for taste panel evaluation. The carcass weight-range targets were 21-26 kg for crossbred lambs and 16-21 kg for Blackface lambs, while a fat class 3L was required for all lambs. When it was not possible to source sufficient 3L lambs in an enhanced farm group, a 3H lamb was taken and, where possible, a 3H lamb from the basal group was used to match this. On the same day in each abattoir a farm was identified at the abattoir to act as the basal farm. For basal farms, the carcass weight requirement was 19±1.5 kg for crossbred lambs and 14.5±1.5 kg for Blackface lambs, with a fat class of 3L (or 3H). Half of the selected enhanced farm or basal farm carcasses were subjected to an enhanced abattoir procedure and the other half to a basal abattoir procedure. Both the enhanced and basal carcasses were further split for short or longer conditioning (left (5d) and right (10d) sides). Two carcasses from each farm (one ES/one non-ES) were selected just before boning on the basis of weight, grade and pH. A total of 96 carcasses, (two sides, 192 samples in all) were sampled across the four visits to each of three abattoirs.

Sensory panel (trained taste panel)

<u>Cooking</u>
Prior to the morning of sensory assessment, samples were removed from the freezer and initially thawed at room temperature and then stored overnight in a refrigerator set at 4ºC. Loin steaks were cut into ten, 2cm thick steaks. Loin steaks were cooked, turning every 3 minutes, under the grill of a household Tricity cooker until the internal temperature of the lamb, as measured by a hand held thermocouple, reached 75ºC in the geometric centre. The lamb was then placed in a GENLAB holding oven set at 60ºC, until sub-sampled and cut into sections approximately 2 x 2 x 2 cm, removing fat and connective tissue. These were wrapped in pre-coded aluminium foil and served to individual assessors.

<u>Sensory Assessment</u>
Sensory assessors were screened and selected on the basis of their ability to discriminate and describe a list of attributes. The initial screening followed the recommendations given in British Standard BS7667, Part 1 [Guide to the selection, training and monitoring of selected assessors]. Further training in the assessment of lamb was carried out by an adaptation of that for pork as outlined in Wood et al. (1995) and Sañudo et al. (1998)[1].

Ten assessors (all female, age range 25 – 60) formed the panel. They were asked to rate samples on an 8 point scale for:

- texture (1 = extremely tough to 8 = extremely tender),
- juiciness (1 = extremely dry to 8 = extremely juicy),
- lamb flavour intensity (1 = extremely weak to 8 = extremely strong),
- abnormal flavour intensity (1 = extremely weak to 8 = extremely strong).

All assessments were completed in a purpose-built panel room, illuminated with red light, comprising individual booths each fitted with a sensory computer that facilitated direct entry of results by the

[1] Wood, J.D., Nute, G.R., Fursey, G.A.J. and Cuthbertson, A. (1995) The effect of cooking conditions on the eating quality of pork, Meat Science, 40, 127-135 and Sañudo, C., Nute, G. R., Campo, M. M., María, G., Baker, A., Sierra, I., Enser M. E. and Wood, J. D. (1998) Assessment of commercial lamb meat quality by British and Spanish taste panels, Meat Science 48, 91-100.

assessors. The order of sample presentation was structured to reduce the influence of first-order carry over effects.

Statistical design and analyses

It is important that the conclusions from this study can be applied across a range of farming and processing conditions, each of which will be slightly different. This study was carefully designed at every level to achieve robust results. Careful design of the study also maximised the information available and thus ensured the resources were used to maximum effect.

There are three main design elements. The first of these is the identification of suitable live animals for processing; the second the design of the processing of the animals to give samples for evaluation and the third the design of the sensory testing of the samples.

Taking each of these levels of design in turn:

1. Twenty-two farms supplied lambs, which conformed to the enhanced farm specification, to the three co-operating abattoirs. The lambs were killed, at each abattoir, between September 2003 and March 2004. On each of these occasions, basal lambs were sourced from two farms submitting lambs on that day. Information was collected from the enhanced farms on the diet. Basal farms sampled were structured to reflect the normal throughput of each abattoir. Carcasses matched the enhanced carcasses in terms of breed type and conformation/fatness score, but were lighter in weight.

2. In the two abattoirs where LVES was applied, three to four carcasses, complying with weight, grade and conformation criteria, were selected at the grading station and moved to a separate line where LVES was applied (90 volts, for 60sec). A similar number of carcasses were selected from the basal farms and treated in a similar manner. Further carcasses, which had been allowed to progress to the chiller without stimulation, were selected as abattoir basal samples. At the third abattoir, HVES was applied automatically and so it was the non-stimulated samples which were selected and removed from the line so as to avoid stimulation.

   At boning, one carcass from each treatment was selected which conformed to pH criteria (i.e. not greater than pH 5.8 at boning). Both loins were collected and left sides allocated to 5d conditioning and right sides to 10d conditioning. In this way a very precise measure of conditioning time was built into the design.

3 As a side-by-side comparison allows assessors to make more precise judgements on differences between samples, the sensory panels were designed to allow as direct comparison of treatments as possible. At each session, assessors received two samples from left and right sides of the same lamb. Hence, both samples had received the same processing procedure for both farm and abattoir. In the three panels immediately following, they received similar samples, but with either a different farm or different abattoir processing regime until all four combinations of basal or enhanced farm or abattoir regimes had been tested. The sequence was repeated for the final four sessions of the morning for samples from the same abattoir, but a different kill date. Different combinations of kill date were combined on different days.

Clearly, simple analysis of such a complicated data set would not do justice to the quality of the data collected with such meticulous care. More importantly, simple analysis would run the risk of coming to misleading conclusions.

There are many advantages in developing a one-stage analysis that allows both design aspects from the measuring process and from the source of the samples to be integrated. This form of analysis, which is known as meta-analysis, is widely used in clinical trials in human and veterinary medicine. In agriculture it is used to integrate data from variety trials carried out at different centres in the UK and in different years. It is only comparatively recently (since 1990) that such techniques have become widely available in specialised statistical packages.

A model with several random (error) terms, together with fixed terms was fitted using Residual Maximum Likelihood (REML). The statistical program Genstat was used for this purpose.

The Fixed model was

Order (of testing) + Breed + Abattoir*Season*Farm Protocol*Processing*Conditioning

and the Random model

Assessor/Day/Block/Session/Order+Kill/Animal/Sample

The Random model was shown to be justified by the data using tests of differences in deviances.

RESULTS

Treatment effects on carcass characteristics

Carcass weights and grades

Table 3. Distribution of carcass weights (kg) between the farm protocol groups

Breed	**Farm Protocol**	**Weight categories**			
		≤16	**>16 ≤19**	**>19**	**Total**
Blackface	Basal	11	5	0	16
	Enhanced	0	13	3	16
		≤20.5	**>20.5 ≤23**	**>23**	**Total**
Crossbred	Basal	32	0	0	32
	Enhanced	1	16	15	32

Enhanced lambs were pre-selected from within the batch to maximise weight differences between them and the basal lambs. Where insufficient enhanced lambs of a higher weight category were available, the corresponding basal lambs were selected at a lower weight, producing the distributions shown (Table 3). This strategy was very successful as enhanced lambs sampled for sensory analysis were significantly heavier than basal lambs, by 3.1 kg for Blackface and 4.4 kg for crossbred lambs (Table 4). Similarly, selection for fat class was also very successful as there was no difference between groups overall.

It was difficult to obtain precise data on breed of crossbred lambs as some farmers run more than one ram type. On average the genetic contribution from the different breeds involved in the production of the crossbred lambs was: 35% Texel, 20% Suffolk 15% Blackface, 15% Blue Faced Leicester, 10% Cheviot and 5% Others.

Table 4. Average carcass weights (kg) and Numeric Fat Class in each farm protocol group

Farm Protocol	Farms (N°)	Animals (N°)	Av. Carcass Weight (kg)	Fat Class (Numeric)[a]
Blackface				
Basal	8	16	15.4	11.3
Enhanced	8	16	18.5	11.3
Crossbred				
Basal	15†	32	18.8	11.3
Enhanced	14*	32	23.2	11.5

[a] carcass grades are first converted to numerical values (as shown in Appendix 2, Table 2.4) before statistical analysis of these values
† Sample number from 2 farms doubled, 2 other farms sourced only one sample each
* Sample number from 2 farms doubled

Table 5. Distribution of conformation between the farm protocol groups

Farm Protocol	E	U	R	O	Total
Basal	0	6	34	8	48
Enhanced	1	13	32	2	48

Table 6. Distribution of carcass fatness between the farm protocol groups

Farm Protocol	3L	3H	Total
Basal	40	8	48
Enhanced	36	12	48

The objective of increasing carcass weight whilst maintaining levels of carcass fatness was achieved. Enhanced lambs had slightly better conformation, on average (Table 5), but overall carcass fatness did not differ, despite the small differences in distribution between grades (Tables 4 and 6). (As explained earlier, only a small proportion of each batch of lambs submitted from enhanced farms went forward for a comparison of enhanced and basal processing, and then to taste panel evaluation. Where possible, carcasses of fat class 3L were sampled from enhanced farms. Table 2.3 in Appendix 2 shows that only 57% of carcasses from enhanced farm batches met this target fat class at the participating abattoir dealing exclusively with crossbred lambs. This figure was similar to the estimate (62%) for the entire kill in the same four sampling months at this abattoir, suggesting that there is substantial scope to improve selection of lambs for slaughter.)

Carcass pH and temperature

Table 7. The pH values of lamb carcasses in the three plants

Farm Protocol	Basal		Enhanced		Sed	Sig		
Processing	Basal	Enhanced	Basal	Enhanced		Farm	Processing	Interaction
Plant 1								
pH 2h	6.61	6.34	6.69	6.29	0.068	ns	***	Ns
pH 24h	5.70	5.63	5.68	5.60	0.033	ns	***	Ns
Plant 2								
pH 2h	6.68	6.28	6.80	6.36	0.096	ns	***	Ns
pH 24h	5.77	5.66	5.73	5.68	0.044	ns	***	Ns
Plant 3								
pH 2h	6.60	6.08	6.64	6.04	0.092	ns	***	Ns
pH 24h	5.72	5.62	5.72	5.65	0.034	ns	***	Ns

In all tables Sed = standard error of difference; Sig = level of significance, ns = not statistically significantly different, *** = P<0.001; ** = P<0.01; * = P<0.05

Basal and enhanced farm protocols had no effect on pH, but the enhanced processing protocol did (Table 7). Plant 3 operated a High Voltage Electrical Stimulation (HVES) unit and in the other two plants, staff of the consortia used a mobile Low Voltage Electrical Stimulation (LVES) Unit to carry out stimulation on selected carcasses. The results in Table 7 demonstrate that the stimulation was successful as all enhanced processed carcasses had a lower pH at 2 hours post-stun than the basal processed carcasses. On average, LVES reduced the pH by 0.3-0.35 units whilst the HVES unit reduced the pH by 0.6 units. There were no differences in pH between basal and enhanced processed samples at 24h post-stun when carcasses had virtually reached their ultimate pH. Values were still a little higher than the 5.50, which might have been expected, but this was probably achieved in the next 12-24h. It is noteworthy that no carcasses had to be rejected because of having an ultimate pH>6.00, i.e. there were no dark, firm, dry (DFD) carcasses from stressed lambs. There is a paucity of research results relating to DFD in lamb, as its occurrence is much rarer than in beef, for example. Sheep are more tolerant of harsh conditions and only extremes such as those imposed by high temperatures and long journey times, such as might be experienced in Australia, produce notable occurrences of DFD meat.

Table 8. Average temperatures of carcasses and time from kill to chill for the three plants

	Temperature 2h (ºC)	Temperature 24h (ºC)	Time from kill to chill (min)
Plant 1	18.5	2.4	30
Plant 2	17.6	0.8	11
Plant 3	15.6	1.4	16
Sed	1.76	0.95	5.6
Sig	Ns	**	***

In general, all three plants had a fairly rapid rate of chill, with plant 2 getting the carcasses into chill the fastest and running the final chiller temperature slightly colder than the other two plants. This was an export plant that desired to chill the carcasses below 7ºC and move them as quickly as possible. Plant 3 had the highest rate of initial chill. [Having reduced the temperature by some 15ºC in 2 hours, it is quite likely that the temperature would have dropped below 10ºC in the next 8 hours. Hence, some degree of cold-shortening might have been expected.

Individual treatment effects on eating quality

Effect of Breed

Table 9. The sensory characteristics of lamb, assessed by a trained taste panel, according to breed category

	Blackface	Crossbred	Sed	Sig.
N	16	32		
Texture (1-8 scale, high = more tender)	5.42	5.10	0.534	ns
Juiciness (1-8 scale, high = more juicy)	5.03	4.82	0.265	ns
Lamb flavour (1-8 scale, high = stronger flavour)	3.78	3.92	0.268	ns
Abnormal flavour (1-8 scale, high = stronger flavour)	2.34	3.24	0.299	**

There were no significant breed effects for texture, juiciness or lamb flavour (Table 9). Blackface lambs were all sourced after the New Year through 2 of the 3 abattoirs, so they would be at similar age at slaughter to crossbred lambs born a couple of months earlier. Crossbred lambs had a significantly higher strength of abnormal flavour over Blackface lambs but both breeds were in the ‘very’ to ‘moderately’ weak abnormal flavour range. These results suggest breed differences in lambs are unlikely to be detected by consumers in terms of eating quality.

Effect of Farm Protocol

Table 10. The sensory characteristics of lamb, assessed by a trained taste panel, according to farm protocol category

	Basal	Enhanced	Sed	Sig.
N	48	48		
Texture (1-8 scale, high = more tender)	5.30	5.22	0.164	ns
Juiciness (1-8 scale, high = more juicy)	5.01	4.84	0.078	*
Lamb flavour (1-8 scale, high = stronger flavour)	3.87	3.83	0.067	ns
Abnormal flavour (1-8 scale, high = stronger flavour)	2.83	2.75	0.083	ns

Results show no changes for texture, lamb flavour or abnormal flavour of lamb from the application of enhanced practices on farms, in transport and pre-slaughter (Table 10). Enhanced farm practices produced meat which was significantly less juicy by 0.17 of a unit, suggesting that increasing the weight of lambs whilst maintaining leanness may have produced a small reduction in juiciness. This was sufficiently small that it is unlikely to be detectable by consumers in relation to eating quality. The main concern from previous studies was tenderness, which was not significantly affected here. Application of the farm protocols with regard to diet monitoring, liveweight changes etc did not enhance eating quality, but may still be useful to screen out extreme practices known to affect eating quality.

We deliberately selected the heaviest lean lambs for the eating quality trial, to provide the most rigorous test of whether or not this affects eating quality. The crossbred lambs selected from the enhanced treatment were 4.4 kg heavier than basal lambs, whilst enhanced Blackface lambs selected were 3.1 kg heavier (Table 3). This was done to test the extremes. Whilst the farm protocols applied are only likely to increase average carcass weight by approximately 1.0 kg (see Appendix 2 Table 2.2), other methods of increasing lamb carcass weight, such as the use of entire lambs or the use of genetically improved rams, could be used. These techniques remain as options for abattoirs and their procurement groups to pursue if they wish to do so. The results from this part of the trial suggest that increasing carcass weight could be pursued without worrying about reducing lamb eating quality, although it would be prudent to test the effect of using ram lambs later in the season.

Effect of Processing

Table 11. The sensory characteristics of lamb, assessed by a trained taste panel, according to processing category

	Basal	Enhanced	Sed	Sig.
N	48	48		
Texture (1-8 scale, high = more tender)	4.56	5.96	0.164	***
Juiciness (1-8 scale, high = more juicy)	4.94	4.92	0.078	Ns
Lamb flavour (1-8 scale, high = stronger flavour)	3.80	3.91	0.067	Ns
Abnormal flavour (1-8 scale, high = stronger flavour)	2.81	2.77	0.083	Ns

There was a clear and highly significant effect of in abattoir processing treatment on the eating quality of lamb (Table 11). The enhanced treatment produced an increase in the rating for texture of 1.4 units which is very large in sensory terms, increasing the rating for lamb from slightly tough/tender to moderately tender on average. There were no effects of processing on juiciness, lamb flavour or abnormal flavour. There was no suggestion that juiciness declined with increasing tenderness as had been seen in the beef trial.

Effect of Conditioning

Table 12. The sensory characteristics of lamb, assessed by a trained taste panel, according to conditioning time (days)

Conditioning time (days)	5	10	Sed	Sig.
N	96	96		
Texture (1-8 scale, high = more tender)	5.09	5.43	0.061	***
Juiciness (1-8 scale, high = more juicy)	4.94	4.92	0.049	Ns
Lamb flavour (1-8 scale, high = stronger flavour)	3.80	3.90	0.039	**
Abnormal flavour (1-8 scale, high = stronger flavour)	2.81	2.77	0.048	Ns

It was possible to carry out a very precise measure of the effect of conditioning on eating quality, as this was done on paired sides from each lamb. Conditioning improved texture (more tender) by around half a point across all treatments and also significantly increased the flavour of lamb.

Effect of Season

Table 13. The sensory characteristics of lamb, assessed by a trained taste panel, according to month of kill category

	Sept	Nov	Jan	March	Sed	Sig.
N	24	24	24	24		
Texture (1-8 scale, high = more tender)	5.13	5.52	5.12	5.27	0.370	Ns
Juiciness (1-8 scale, high = more juicy)	4.90	4.87	4.94	5.00	0.180	Ns
Lamb flavour (1-8 scale, high = stronger flavour)	3.91	3.94	3.81	3.75	0.174	Ns
Abnormal flavour (1-8 scale, high = stronger flavour)	2.28^{a}	2.39^{a}	3.31^{b}	3.19^{b}	0.199	***

^{ab} values with different superscripts within a row are significantly different

Overall season had no effect on texture, juiciness or flavour but there was an increase in the abnormal flavour strength for old season lamb in January and March.

Table 14. The sensory characteristics of crossbred lamb processed through plant 3, assessed by a trained taste panel, according to month of kill category

	Sept	Nov	Jan	March	Sed	Sig.
Average age at slaughter (days)	180	212	282	329		
Texture (1-8 scale, high = more tender)	5.22	4.83	4.80	5.00	0.316	ns
Juiciness (1-8 scale, high = more juicy)	4.72	4.54	4.61	4.92	0.187	ns
Lamb flavour (1-8 scale, high = stronger flavour)	3.98	3.89	3.68	3.90	0.187	ns
Abnormal flavour (1-8 scale, high = stronger flavour)	2.56^{a}	2.83^{ab}	3.51^{c}	3.19^{bc}	0.0.28	**

^{abc} values with different superscripts within a row are significantly different

Table 14 shows data from plant 3 only, because in this plant all lambs were crossbred lowland types throughout the seasons. Stronger abnormal flavour was a significant feature in the later season, older, crossbred lambs. Blackface lambs killed in Jan and March at plants 1 and 2 averaged 2.34 for abnormal flavour score. Higher abnormal flavour values may be an age effect, or could be due to diets, e.g. forage brassicas. Interpretation should recognise that values are still in the low range of the scale (moderate to very weak) and that comparisons between kill dates were among the weaker tests. The effect of diet upon strength of abnormal flavour in late season lambs would be an area worth further research. New Zealand research has shown that a diet change can change extremes of flavour within 4-8 weeks in cattle.

Table 15. The sensory characteristics of lamb, assessed by a trained taste panel, according to diet

	Brassica based	Concentrates only	Grass only	Grass+ Concentrates	Sed	Sig.
N	7	2	6	7		
Texture (1-8 scale, high = more tender)	5.08	6.02	5.68	4.74	0.754	Ns
Juiciness (1-8 scale, high = more juicy)	4.66	4.59	5.07	4.66	0.216	Ns
Lamb flavour (1-8 scale, high = stronger flavour)	3.86	3.90	3.75	3.92	0.260	Ns
Abnormal flavour (1-8 scale, high = stronger flavour)	2.99	2.61	3.05	2.94	0.250	Ns

An attempt was made to determine if there was any systematic variation associated with diets fed in relation to eating quality, focussing on the finding of an increase in abnormal flavours in lambs killed in January and March compared with September and November. Typically lambs would be finished on grass only early in the season, grass plus concentrates and brassica-based diets as the season progressed, with ad lib concentrates being used to finish the slowest growing lambs on any system. The 22 enhanced farm diets were categorised as: Brassica based (7), *ad lib* concentrates (2), grass only (6) and grass + concentrates (7). In the subsequent analysis there were no significant effects of diet on any of the sensory attributes. Values for abnormal flavour were 2.6 (lowest) for ad lib concentrate vs. around 3.0 for the rest (s.e.d.0.25, ns). However, with only 2 samples from each of two farms using this system this is very weak evidence on which to draw conclusions. There was no clear evidence from this project that an increase in abnormal flavour over the season was caused by a specific diet. This problem needs to be investigated with a specifically designed experiment.

Combined effects on eating quality

Farm Protocol and Processing

Table 16. The sensory characteristics of lamb, assessed by a trained taste panel, according to farm protocol and processing categories

Farm Protocol	Basal		Enhanced		Sed	Sig.
Processing	Basal	Enhanced	Basal	Enhanced		Interaction
N	24	24	24	24		
Texture	4.61	5.98	4.52	5.93	0.230	Ns
Juiciness	5.07	4.96	4.81	4.88	0.110	Ns
Lamb flavour	3.80	3.94	3.79	3.87	0.096	Ns
Abnormal flavour	2.92	2.75	2.70	2.80	0.118	Ns

There were no significant interactions when both farm and abattoir processing treatments were included in the analysis, i.e. both sets of meat behaved in the same manner regardless of farm of origin with enhanced processing increasing tenderness and flavour.

Farm Protocol and Conditioning time

Table 17. The sensory characteristics of lamb, assessed by a trained taste panel, according to farm protocol and conditioning time (days)

Farm Protocol	Basal		Enhanced		Sed	Sig.
Conditioning time (days)	5	10	5	10		Interaction
N	48	48	48	48		
Texture	5.11	5.48	5.08	5.37	0.145	ns
Juiciness	5.02	5.01	4.86	4.83	0.084	ns
Lamb flavour	3.82	3.93	3.79	3.87	0.070	ns
Abnormal flavour	2.89	2.77	2.72	2.78	0.086	ns

Similarly there were no interaction between pre slaughter treatments and conditioning, all lambs benefiting from its effects on tenderness and lamb flavour.

Processing and Conditioning

Table 18. The sensory characteristics of lamb, assessed by a trained taste panel, according to Processing and Conditioning time (days)

Processing	Basal		Enhanced		Sed	Sig.
Conditioning time (days)	5	10	5	10		Interaction
N						
Texture	4.34	4.79	5.85	6.06	0.145	*
Juiciness	5.01	4.87	4.87	4.97	0.084	*
Lamb flavour	3.79	3.81	3.82	4.00	0.070	*
Abnormal flavour	2.77	2.85	2.84	2.70	0.086	*

There were significant interactions between enhanced processing effects and extra conditioning time. Conditioning improved the basal processed lamb by around half a unit but improved the enhanced processed lamb by only 0.15 of a unit. Thus the extra conditioning added little to the tenderness of electrically simulated lamb. However, conditioning slightly reduced the juiciness of basal processed lamb, but increased juiciness of enhanced processed lamb. Also, it increased lamb flavour of enhanced processed lamb whilst reducing abnormal flavour. Taken overall, the extra conditioning gave favourable responses to enhanced processing producing the best combinations of sensory attributes as assessed by a trained test panel.

It is interesting to note that the 5d conditioned samples with enhanced processing are much more tender than the 10d conditioned samples from basal processing. It is probable that electrically stimulated meat with no conditioning would be more tender than the non-stimulated meat with 10d conditioning. Thus it would be viable for plants to install a simple LVES system and retain their rapid throughput, producing more tender meat than they do now, which could be retail packed at cutting thus saving on chiller space. Selected carcasses could be conditioned to produce even more tender meat for specialised markets.

Effect of enhanced processing in the different abattoirs

Table 19. The sensory characteristics of lamb, assessed by a trained taste panel, according to abattoir and processing categories

Abattoir	Plant 1		Plant 2		Plant 3		Sed	Sig.	
Processing	Basal	Enhanced	Basal	Enhanced	Basal	Enhanced		Plant	Int.
N	16	16	16	16	16	16			
Texture	4.88	5.76	4.77	5.90	4.04	6.20	0.348	ns	***
Juiciness	4.95	4.83	4.97	5.20	4.89	4.73	0.172	*	ns
Lamb flavour	3.82	3.94	3.77	4.04	3.80	3.74	0.168	ns	ns
Abnormal flavour	2.81	3.02	2.93	2.82	2.68	2.49	0.192	ns	ns

There was an interaction for texture indicating that samples in the three plants reacted differently to the enhanced processing (two different forms of electrical stimulation). Plants 1 and 2 used low voltage electrical stimulation (LVES). Plant 3 used high voltage electrical stimulation (HVES). Plant 3 appeared to produce slightly tougher lamb at basal levels of processing than plants 1 and 2, but the use of HVES appeared to compensate for this.

HVES increased tenderness by 2.16 units compared to 1.0 unit, on average, for LVES (but note that HVES was applied to crossbred lambs only). Effects of LVES were not consistent on juiciness, reducing it in plant 1 and increasing it in plant 2. HVES reduced juiciness in plant 3. These effects on juiciness were quite small. There were no significant effects of plant on lamb or abnormal flavour. This may account for the earlier observation (Table 11) that improving tenderness did not reduce overall juiciness.

As noted previously, the most precise comparison is for conditioning time as the panel tested this at the same session. Enhanced and basal treatments, both on-farm and in-plant, were the next most precisely compared as they were tested in adjacent sessions within the same half of the morning session. Two kill dates were tested within the same morning from the same plant. The least rigorous test was between plants as these were always tested on different days. Tentative comparisons can be made as the panel is highly experienced and when tested with repeat samples some weeks later have produced very similar results. The larger increase in tenderness produced by HVES than LVES is almost certainly real. The overall average difference in texture between stimulated and non-stimulated carcasses for plants 1, 2 and 3 was 0.88, 1.13 and 2.16 respectively. Plant 3 operated a HVES unit and could therefore move carcasses to chill immediately and employ an initially faster chill (Table 8) without the danger of inducing cold shortening. Hence, this would explain why basal carcasses from this plant tended to be tougher than from the other two (Table 19). They may have experienced some cold shortening, which would not normally have occurred, as all carcasses would normally be stimulated. With HVES they produced some of the most tender meat, although the average tenderness was not statistically significantly different between plants.

Variability of trained taste panel results

The variability of the samples tested by the trained taste panel has been tested simply by taking the variance and 25th Percentile, Median (50th Percentile) and 75th Percentile for the enhanced (E) and matching baseline (B) samples. (The 25th and 75th percentiles are the values of those samples 25, 50 and 75% along the values when they are rearranged by order of value.)

Table 20. Variability of samples assessed by the trained taste panel for texture

Processing	Farm Protocol	Variance	25th Percentile	Median	75th Percentile
Basal	Basal	1.329	3.85	4.52	5.13
	Enhanced	0.786	3.91	4.48	4.99
Enhanced	Basal	0.480	5.37	6.07	6.42
	Enhanced	0.760	5.34	6.06	6.50

Table 21. Variability of samples assessed by the trained taste panel for juiciness

Processing	Farm Protocol	Variance	25th Percentile	Median	75th Percentile
Basal	Basal	0.212	4.65	5.13	5.33
	Enhanced	0.169	4.55	4.82	5.16
Enhanced	Basal	0.188	4.51	4.94	5.19
	Enhanced	0.170	4.65	4.80	5.09

Table 22. Variability of samples assessed by the trained taste panel for lamb flavour

Processing	Farm Protocol	Variance	25th Percentile	Median	75th Percentile
Basal	Basal	0.136	3.52	3.80	4.06
	Enhanced	0.126	3.54	3.84	3.98
Enhanced	Basal	0.178	3.60	3.85	4.22
	Enhanced	0.109	3.54	3.85	4.08

Table 23. Variability of samples assessed by the trained taste panel for abnormal flavour

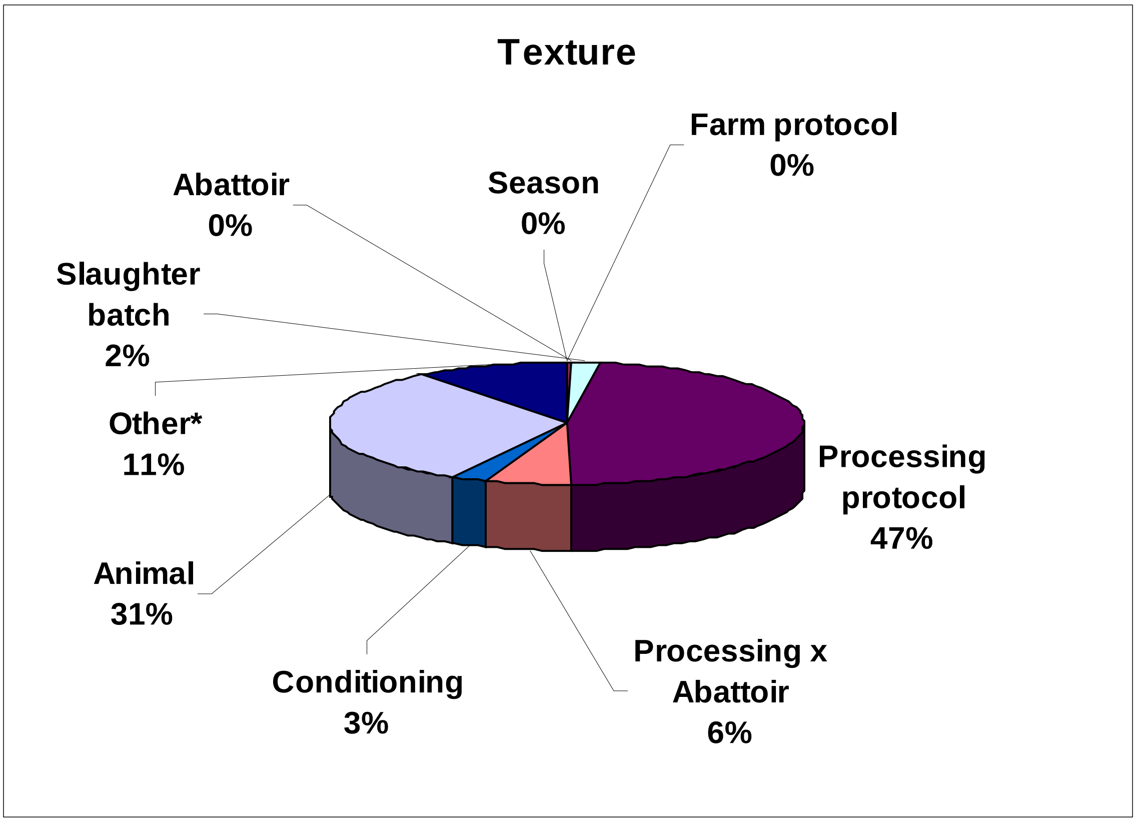
Processing	Farm Protocol	Variance	25th Percentile	Median	75th Percentile
Basal	Basal	0.355	2.61	2.87	3.26
	Enhanced	0.132	2.56	2.76	3.04
Enhanced	Basal	0.172	2.66	2.81	3.10
	Enhanced	0.278	2.68	2.82	3.11

There were few clear patterns in variability of results. There was a tendency for the enhanced farm protocol to reduce variability when followed by basal processing. Also, pooling over both farm protocols, there was less variability in texture in samples from enhanced procedures applied post slaughter.

Overview of sources of variation in eating quality

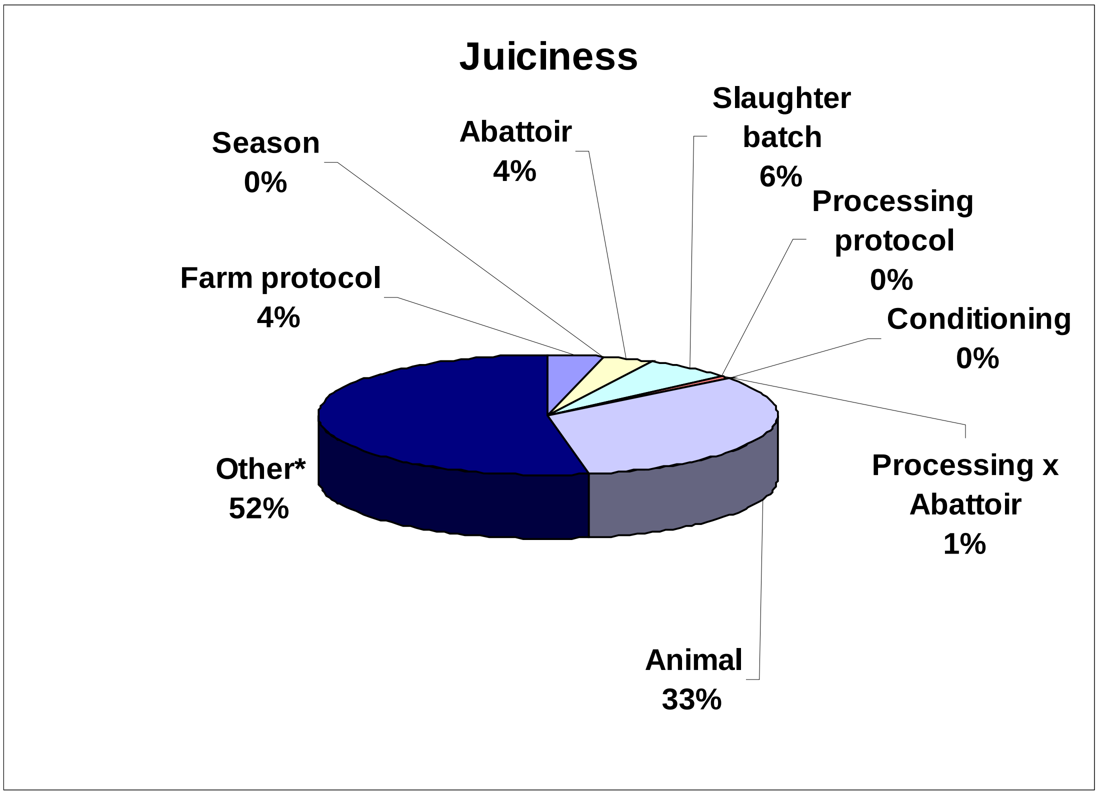
Figures 2 to 5 provide an overview of the main sources of variation in texture, juiciness, flavour and abnormal flavour, as judged by the trained taste panel. These results have been obtained with a much simpler statistical model than that fitted earlier. The aim here is to put in context the proportion of variation accounted for by the on-farm and processing protocols, and to highlight other main sources of variation. The statistical models fitted some effects hierarchically to account for the structure of the data. After fitting on farm and processing protocols, the models fitted slaughter batch within abattoir, farm within slaughter batch, and animal within farm. Breed effects are accounted for largely at the 'farm within slaughter batch' level. Animal within farm accounts for remaining animal-related sources of variation after fitting the other effects. Processing protocol was responsible for a substantial proportion of the variability in texture. A fairly high proportion of the variation in abnormal flavour was associated with season. Substantial proportions of variation in all attributes are attributable to individual animal, but the precise causes of this variation remain poorly understood. There is within-breed genetic variation in many meat eating quality characteristics, and this explains some of this individual animal variation. It is notable that 11%, 52%, 48% and 31% of the variation in texture, juiciness, lamb flavour and abnormal flavour respectively, could not be explained by any of the factors measured in this trial. To some extent this is to be expected. This field trial was designed to test a package of measures expected to improve eating quality, and to investigate the effect of higher slaughter weights, rather than to precisely apportion sources of variation. A tightly controlled experiment may have allowed more of the variation to be accounted for. However, these results are useful in highlighting areas where we need a better understanding to control variability in meat eating quality more effectively.

Figure 2. Sources of variation in texture, as judged by the trained taste panel



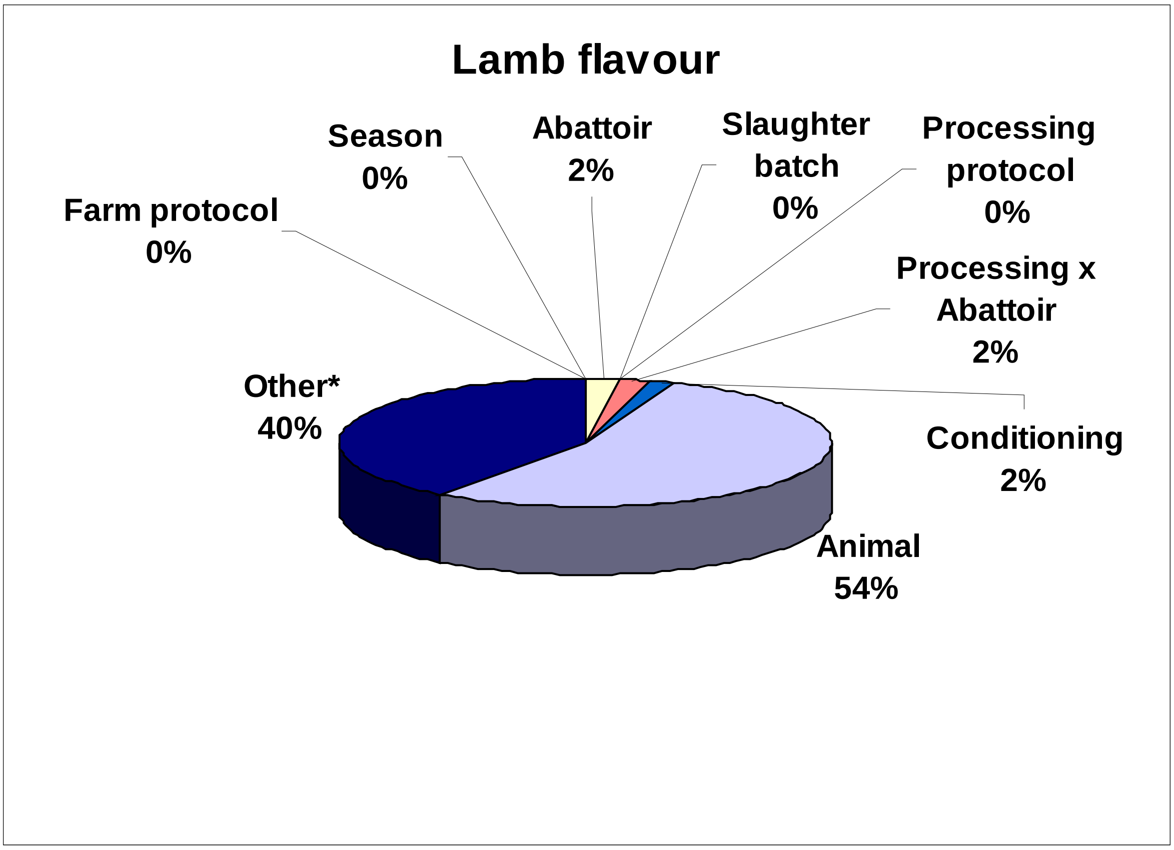
‘Other’ includes measurement error and the small effects of interactions between processing and conditioning.

Figure 3. Sources of variation in juiciness, as judged by the trained taste panel, on samples from the intervention trial



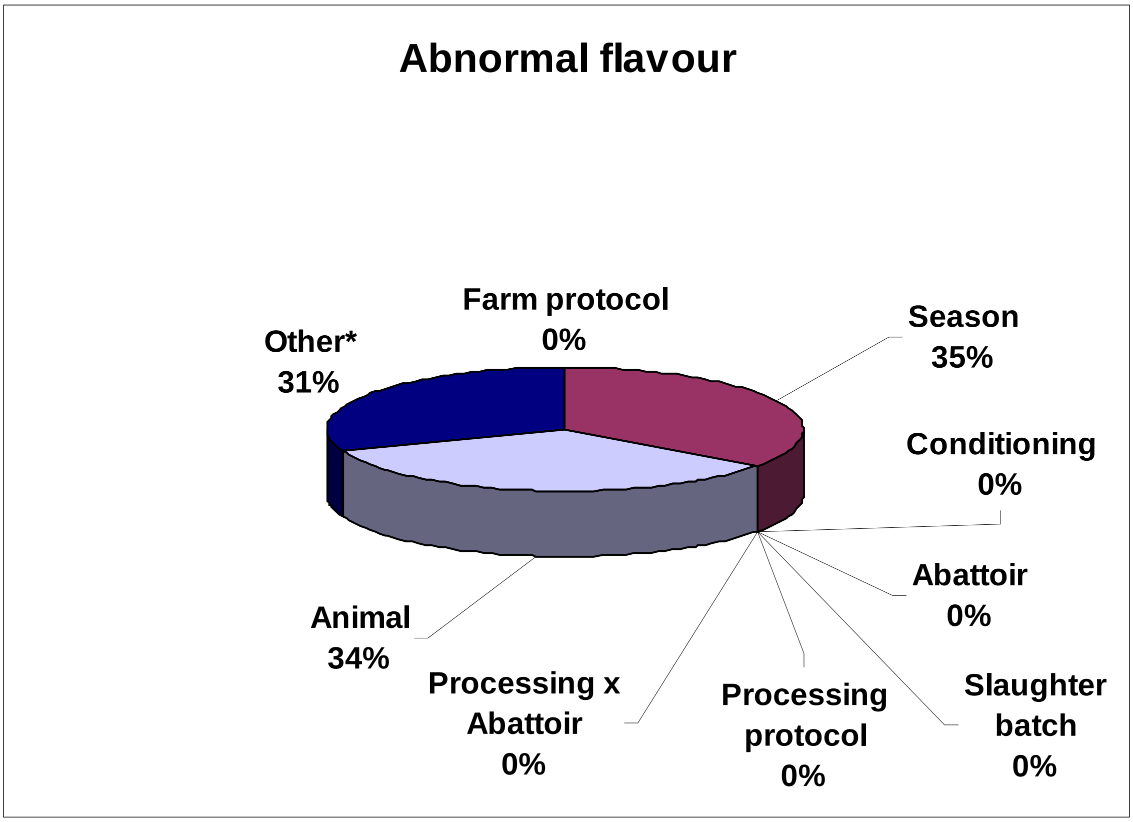
'Other' includes measurement error and the small effects of interactions between processing and conditioning.

Figure 4. Sources of variation in flavour, as judged by the trained taste panel, on samples from the intervention trial



‘Other’ includes measurement error and the small effects of interactions between processing and conditioning.

Figure 5. Sources of variation in abnormal flavour, as judged by the trained taste panel, on samples from the intervention trial



‘Other’ includes measurement error and the small effects of interactions between processing and conditioning.

CONCLUSIONS

- The precise experimental design was effective in detecting, as statistically significant, differences of 0.1-0.2 units in eating quality attributes on the 1-8 scale used by the trained taste panel.

- It is possible to select heavier carcasses (>16 kg for Blackface and >23 kg for crossbreds) with acceptable fatness (3L) without deleteriously affecting texture or flavour, the main components of eating quality. There was a suggestion that this meat may be less juicy and this needs further investigation.

- A significant proportion of carcasses failed to meet target fat class, suggesting substantial scope to improve selection of lambs for slaughter.

- It is well known from other studies that low growth rates, growth checks and stressful handling of animals, can negatively affect meat quality. In this study, enhanced pre-slaughter protocols had little effect on sensory attributes compared to those of the basal sample. Apart from the weight of lambs they submitted, basal farms were not deliberately chosen to have contrasting management practices to enhanced farms. Basal farms were intended to reflect typical throughput for that abattoir, at that time. The fact that no significant effect of the pre-slaughter enhanced protocol was detected here may be due to good practice in the basal farms supplying the participating abattoirs. Hence, care must be taken to adhere strictly to 'best practice' guidelines, and to avoid factors known to negatively affect meat quality.

- Post-slaughter enhanced processing and conditioning had a major, positive impact on the average level of most attributes of lamb eating quality and improved consistency in texture.

- The improvement in eating quality due to post-slaughter enhancement occurred across all breeds, abattoirs and pre-slaughter treatments.

- Electrical stimulation had a much greater impact in improving meat texture than the length of time meat was conditioned.

- Seasonal effects were minor and whilst texture did not deteriorate, the trained sensory panel did detect an increased abnormal flavour in late season lamb. This was significantly higher in crossbred than Blackface lambs. There was no clear evidence from this project that an increase in abnormal flavour over the season was caused by a specific diet. This problem needs to be investigated further with a specifically designed experiment.

- The enhanced processing protocol was particularly effective in controlling consistency in texture, but less so for consistency of other meat quality measures. Season accounted for a high proportion of variation in abnormal flavours. Substantial proportions of variation in all meat quality measures are attributable to individual animal. The precise cause of this variation remains poorly understood, but it is highly likely to include genetic variation within breed. The more detailed results presented in the report are useful in highlighting areas where we need a better understanding to control variability in meat eating quality.

APPENDIX 1: FARMER PROTOCOLS

Farmer collaborators guide to the QMS lamb eating quality trial

To maximise eating quality and consistency of weaned lamb and reduce processing costs, lambs should grow to their potential maximum carcass weight without severe checks to growth. Larger, leaner lambs are needed, increasing returns for both farmer and abattoir. This trial examines the effects of on- farm procedures and abattoir practices designed to increase carcass weights of Blackface lambs to 16+kg and crossbred lambs to 21-25 kg and to study the effects of this on eating quality.

Research shows that higher carcass weights can be achieved consistently through a combination of improved genetics (sire selection), selecting the right lamb and the right diet together with accurate assessment of condition to avoid over fatness at slaughter. An initial selection through your producer group has identified your farm as consistently producing high quality heavier lambs using improved genetics without over fatness and with good finishing conditions. To maximise the potential carcass weight a technical information sheet to assist you reduce weaning check of lambs has been attached. Please read this and where possible implement the advice. **(This information sheet is reproduced in the final section of this Appendix 'Avoid the weaning check by reducing stress'.)**

Please inform your trials organiser when you will be weaning and agree a visit to organise the trial at around 1-2 weeks post weaning.

Research shows that lambs, which are the heaviest at weaning within a group, are heaviest at slaughter and most likely to meet the higher target weight range. Lambs for the trial will be wethers only.

Trial procedures

Shortly after weaning the trials organiser will visit and inspect weaned lambs, wethers will be separated from the rest of the lambs and divided into above average and below average on the basis of size. Within the above average group the leaner lambs and longer lambs will be selected for the trial. A sample of at least 40 of these will be weighed and the weight compared with a sample of around 25 lambs from the smaller non-selected wether lambs to check that they are the heaviest. Lambs allocated to the trial will be tagged (to aid identification) or existing tag numbers recorded and should be finished on your normal system with the rest of your lambs at the usual time of the year, but they are not to be put through a severe store period. A severe store period is weight loss for 1 month or maintenance for more than 3 months. The trials organiser will collect information on your expected diets during the finishing phase and the information will be sent to SAC nutritionist Mitch Lewis who will determine whether there are potential protein shortages and when this is likely to happen, forage samples will be taken (where conserved grass products are fed) and advice given prior to the finishing period on supplementation (inclusion of higher protein feeds etc.). A target experimental kill date will be agreed that fits in the middle of your normal slaughter date range.

1-2 weeks prior to the expected experimental kill date the trials organiser will visit and identify at least 8 lambs for the selected kill date, all these will be consigned to the abattoir on the agreed date and 4 of these will go forward to the eating quality trial (this allows us to select more closely to the 3L fatness target). On the same day in the abattoir 4 random lambs from those consigned that day by other farms will be selected as controls. Half of the experimental and control lambs will be treated to enhanced post slaughter abattoir treatments, this way we can quantify the relative effects of farm and abattoir procedures on eating quality.

Summary of protocols for weaned lambs

- Lambs for the trial have to be Scottish castrates under one year old and target fat class 3L.

- They have to have been reared on the ewe and finished on a planned system appropriate to the growth potential of the lamb (set by breed) and current liveweight and condition.
- To ensure high eating quality the trials organiser will check that the identified finished group has the correct weight and condition consistent with the expected finishing date and target carcass weight and that the lambs are being fed on an appropriate feeding regime and with a selection system for finished lambs capable of identifying fat class 3L lambs.
- The lambs will be identified as a group by their UK tag number and by individual tag numbers.
- A deadline slaughter date range and carcass weight range will be set allowing for variation within the group beyond which all lambs will be off the trial.
- Once lambs are identified under the trial there have to be no major dietary changes (apart from minor changes to supplementary rates to achieve finishing during the finishing period).
- Abattoirs will accept all lambs consigned on the agreed experimental kill date that meet fat class 3L and you will be provided with full payment for all kilos.
- Any lambs not meeting the specification in relation to fatness and conformation will be paid at the normal rate.
- Close liaison with the trials organiser will be required prior to the date of consignment to ensure the lambs will be ready and that the team responsible for applying in abattoir treatments, monitoring lambs and collecting meat samples are fully prepared and informed.

Avoid the weaning check by reducing stress

Typically, lambs grow at high rates of gain, e.g. 280 g/d from 6-12 weeks of age, but growth rate after weaning is often only 50-100 g/d. There are several reasons for this – worms, stemmy pasture, lambs having slower growth potential close to finishing weight and falling amounts of feed. Performance of lambs on clean aftermath grazing is often disappointing in relation to the chemical analysis of grass on offer due to weaning stress.

Weaning stress contributes to this lower growth rate and may also reduce lamb eating quality. We now recognise five components of weaning stress:

- Separation from the dam (psychological)
- Loss of milk (nutritional)
- Handling stress in pens
- Stress from the action of dosing
- Fear of the new environment when moved to clean pastures

Current practices seem designed to maximise stress on the lamb by having all these components acting together to push the lamb into greater susceptibility to disease, particularly worm infection, through reduced immune response.

One way of reducing stress is to wean lambs back onto the pasture they were on before weaning. The advantages are that the lambs know where water supplies are and are not afraid. Where the existing pasture is contaminated with worms, it is possible to dose lambs with conventional drench two weeks before weaning and again one or two weeks after weaning when they can be moved to clean aftermaths. Alternatively, pasture can be ‘cleaned up’ using long-lasting action wormers prior to weaning. If for instance Cydectin oral is used at 3 weeks pre-weaning, any lambs ready for sale at weaning will be outwith the withdrawal period and remaining lambs will still have 2 weeks protection.

APPENDIX 2: DEVIATIONS FROM PROTOCOL AND ADDITIONAL DATA ON CARCASS WEIGHTS AND GRADES

Table 2.1 Deviations from protocols with comments

Component of Protocol	Deviation	Comment
Number of farms sampled	One baseline and one enhanced batch of crossbred lambs were sourced from the same farm, in two different seasons (September and March) Additionally, normal sampling numbers (two animals) were doubled to four animals on the same kill day for two enhanced and two baseline farms, to achieve target numbers, when scheduled deliveries were cancelled	Possible reduction in variability by repeating farms
Carcass weight	5 baseline Blackface lambs were slightly overweight (+1 kg carcass), 6 enhanced crossbred lambs were slightly underweight (-1 kg carcass)	Despite this, large differences in weight between the enhanced and baseline lambs sampled on each day of kill were achieved

Table 2.2 Batch average carcass weight (kg) and fatness, according to farm protocol and breed categories

Farm Protocol	Farms (N°)	Animals Consigned (N°)	Av. Carcass Weight (kg)	Fat Class (Numerical scale)
Blackface				
Basal	8	149	17.1	11.2
Enhanced	8	196	18.4	11.4
Crossbreds				
Basal	15	890	20.1	12.1
Enhanced	14	368	21.1	12.3

Result from ‘Batches’ refers to the total of all lambs presented as enhanced by the producer on the kill day. The value of this batch data is that it identifies the size of the increase in carcass weight that is achievable through the simple on-farm procedure of identifying heavier wether lambs at weaning. The Blackface and crossbred carcasses were 1.3 kg and 1.0 kg heavier than their basal farm counterparts, respectively.

Table 2.3 shows the carcass weights achieved by 3L lambs from the enhanced group versus the 3L lambs from the whole months kill at plant 3, which dealt exclusively with crossbred lambs. This shows a similar advantage of around 1.0 kg in carcass weight from selecting for heavier wether lambs at weaning.

Table 2.3 Average carcass weight of enhanced vs. abattoir 3L lambs across seasons for plant 3

Season	**Crossbred lambs abattoir mean**			**Crossbred lambs enhanced mean**		
	No.	**Wt (kg)**	***% 3L***	**No.**	**Wt (kg).**	***% 3L***
Sept	n/a	19.1	64	77	20.4	54
Nov	n/a	19.7	58	100	20.2	59
Jan	n/a	19.7	57	25	21	44
March	n/a	19.6	71	9	24.4	90
Mean		*19.5* [a]	*62* [a]		20.5	57 [b]

[a] *Total numbers not known, so assumed equal in the 4 seasons.*
[b] *Based on total number each season.*

Table 2.4 Scale used to convert fat classes to numerical values for statistical analysis

Fat Class	**Numerical Value**
1	4
2	8
3L	11
3H	13
4L	15
4H	17
5	20