MEAT EATING QUALITY – A WHOLE CHAIN APPROACH

Factors Affecting Beef Eating Quality

Final Report to SEERAD

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

EXECUTIVE SUMMARY

The main aim of the trial was to test whether a package of measures applied on commercial farms and abattoirs produced noticeably better meat eating quality and improved consistency. In this 'intervention' study, thirty two participating farms and two participating abattoirs adopted agreed **enhanced** practices, some of which were not already in use. The enhanced meat samples were compared with samples obtained from other farms supplying the same participating abattoir, on the same kill day, and produced under current farm and processor practices (**basal** samples). All the samples were compared by a trained **sensory panel**. Additionally, volunteer households (the **consumer panel**) tested half of the enhanced and basal beef samples at home. Samples from the intervention study were also compared with **'industry random baseline samples'** collected from another 8 Scottish abattoirs. Sample numbers were collected in proportion to current production of these abattoirs, and they were processed using current abattoir practice.

Key findings are:

- Consumers rated the beef overall as of good quality, with a score of around 6 on the scale of 1 (dislike extremely) to 8 (like extremely).

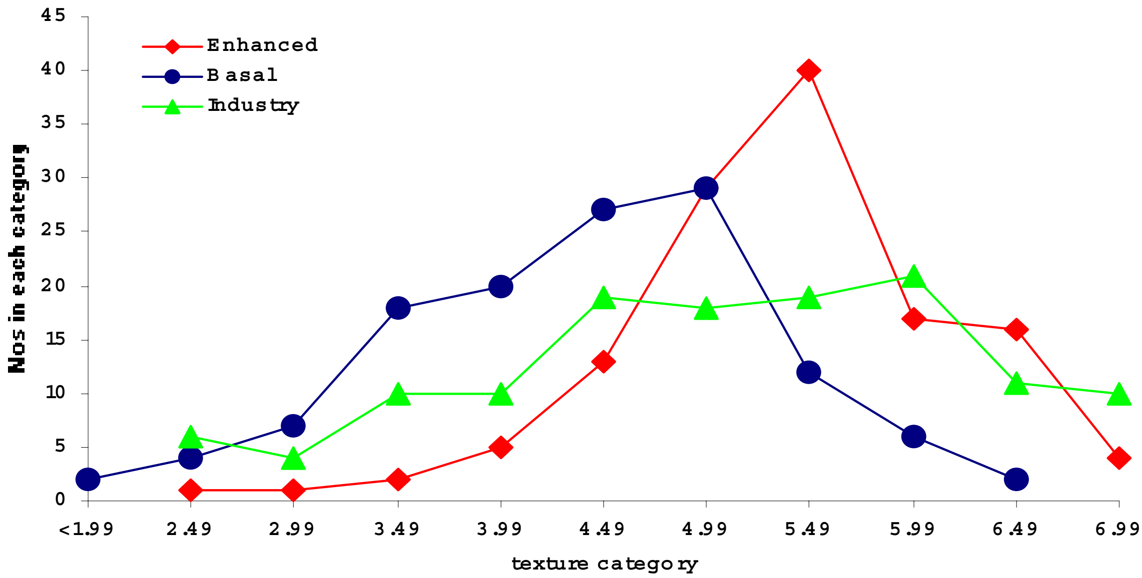
- It is well known from other studies that pre-slaughter factors such as low growth rates, growth checks, recent diet changes, stressful handling of animals, and the use of bulls, unless these are carefully handled, can reduce meat quality. In this study, there was no significant effect of the pre-slaughter enhanced protocol on the sensory panel or consumer panel scores, but this result needs to be interpreted with caution. Basal farms were not deliberately chosen to have contrasting management practices to enhanced farms, but 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 largely due to good practice in the basal farms supplying the participating abattoirs. Hence, care must be taken to adhere strictly to 'best practice' guidelines for rearing and handling cattle, and to avoid factors such as growth checks and stress, known to negatively affect quality.

- Post-slaughter enhanced processing had a major, positive impact on most attributes of beef eating quality. This was true for both abattoirs and their different means of enhancing the eating quality of meat (high voltage or low voltage electrical stimulation and hip suspension). The consumer panel showed a highly significant preference for the abattoir-enhanced processed samples for texture, juiciness, flavour and overall liking.

- Several pre- and post-slaughter factors were responsible for substantial proportions of the variability in texture, juiciness and tenderness, as judged by the sensory panel in the intervention trial. Substantial proportions of variation are attributable to individual farm and individual animal, although the precise causes of this variation remain poorly understood. 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.

- Compared to the industry random sample, enhanced processing produced meat of higher average texture (approaching statistical significance) and significantly higher beef flavour, with more consistent texture (as shown in the graph below) and flavour:

The distribution of taste panel texture values (1 to 8 scale, high = more tender) within the basal processed, enhanced processed and industry random baseline samples



- The purpose of the industry random sample was not to directly compare abattoirs, but to provide a representative sample of meat produced under current industry practice. However, there are some trends that are worth highlighting. The abattoirs responsible for most of the more tender samples employed an enhanced processing procedure, with the tenderness of the meat being further enhanced by conditioning. Those plants that employed conditioning without electrical stimulation or hip suspension did not produce meat that was as tender.

- In view of the substantial improvement in eating quality that followed enhanced processing in the abattoir, and the lower eating quality in those industry random samples from abattoirs that relied solely upon conditioning, it would be valuable to further test enhanced processing procedures such as hip suspension and electrical stimulation, alone or in combination with varying conditioning times, so that the industry has a choice of which processes to adopt for its purpose.

- There was evidence from within the industry baseline samples that bulls produced tougher meat than heifers or steers.

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 current and enhanced practices to consistently deliver meat that will satisfy consumer demands for quality and eating experience.

Scottish meat has a high international reputation for its quality; this is particularly true for Scottish beef, which attracts premiums over other UK sources. Beef, however, is known to be variable in eating quality and comes from a wide variety of breeds and crosses in a wide variety of production systems. Identification of the source of this variation, and how components across the supply chain influence it, is key to improvement of the product. Some of the key practices thought to improve meat eating quality are shown in Table 1 below. Many producers and processors already use some of these 'best practices'. The purpose of this trial was to test, on a wide commercial scale, their implementation as a package, across the supply chain. This work was undertaken within the beef 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
Production from the beef herd using beef sires Production of suckled steers and heifers Feeding of grass and conserved grass products Careful selection to meet specification on carcass weight, fatness and conformation Avoiding growth checks Feeding and managing to achieve reasonable growth rates Avoiding slaughter soon after diet changes Careful handling and transportation of animals Minimising mixing of unfamiliar animals	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 carcasses are chilled rapidly they toughen due to cold shortening. 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. It is extremely difficult to apply to carcasses which vary in conformation (muscle mass) and fat cover and which may be entering the chiller first, when it is at its coldest, or last when the rate of chilling will be much reduced. The solution was the introduction of Low (LVES) or High (HVES) Voltage Electrical Stimulation and/or hip suspension. Electrical stimulation prevents muscle shortening by removing energy stores (glycogen) and HVES, in particular, may have other tenderising effects. Hip suspension holds commercially important muscles in a stretched position, again preventing shortening. These processes allow more rapid chilling and hence more hygienic production and reduced conditioning times.

The MLC Blueprint for tender beef recommends a number of measures during processing (LVES or HVES, hip suspension and/or considerate chilling alone, or in combination with a conditioning period). In this project the brief was to test a package of enhanced processes, believed to be the best combination of these processes, applied together.

In the last 10 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. 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. This project provided the opportunity to test both systems, albeit in different abattoirs. Hence, a combination of LVES, hip suspension and conditioning was tested in one plant and HVES with conditioning in another. Other combinations were tested as a consequence of taking random samples from the rest of the major industry plants, as per the specifications they use currently, without any intervention from the research consortium.

OBJECTIVES AND EXPERIMENTAL DESIGN

The main aim of the trial was to test whether a package of measures applied on farms and in abattoirs noticeably improved meat eating quality. In this 'intervention' study, thirty two participating farms and two participating abattoirs adopted agreed **enhanced** practices, some of which were not already in use. The enhanced meat samples were compared with samples obtained from other farms supplying the same participating abattoir, on the same kill day, and produced under current farm and processor practices (**basal** samples). All samples were compared by a trained **sensory panel**. Additionally, volunteer households (the **consumer panel**) tested half of the enhanced and baseline beef samples at home. Samples from the intervention study were also compared with 'industry random baseline samples' collected from other Scottish abattoirs. Sample numbers were collected in proportion to current production of these abattoirs, and they were processed using current abattoir practice.

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 applying enhanced and basal abattoir treatments to the two sides of each carcass in one abattoir, or by applying these treatments to adjacently-processed animals in the other abattoir.

The trial was thus specifically designed to test the following factors contributing to beef eating quality:

1. Pre-slaughter effects - to examine the effect of implementing enhanced on-farm, transport and pre-slaughter protocols.
2. Post slaughter effects - to examine the effect of implementing enhanced post-slaughter protocols.
3. To obtain a better understanding of interactions between pre- and post-slaughter factors affecting eating quality.
4. To compare the results from the small number of abattoirs involved in testing these enhanced practices with the wider picture derived from the industry random baseline, including a comparison of the variability of meat eating quality in different sample groups.

Enhanced protocols were introduced on farm, through the transport and slaughter process, and during the management of the product post-slaughter, setting up structured comparisons to achieve these objectives.

METHODS

Farm and transport protocols

The design of the protocols to apply on farm/in transport were:

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

Thirty-two farms provided cattle to the enhanced protocol, 16 farms supplying each of the two abattoirs in the study. All participating farms were sent information about the trial, and were checked to ensure that they conformed with the enhanced protocol. Full details of this are given in Appendix I. In brief, animals conforming to the enhanced protocols were:

- Steers or heifers only
- Out of beef suckler cows (cows with a minimum 50% beef) by a beef sire (i.e. slaughtered cattle minimum 75% beef).
- Suckled for at least five months
- Finished on grass or, after a summer on grass, on forage and concentrates in-house
- Growing at an acceptable rate in the finishing period

There was an initial farm visit by a trials officer, to ensure that animals followed the protocol for at least 100 days before the intended slaughter date. A group of cattle of a similar weight were visually identified by the officer as being steers or heifers and of beef breeding and thus suitable for the enhanced protocol. Passports were checked and management numbers/passport numbers recorded, ensuring that animals were born, reared and finished in Scotland and the beef sire breed was recorded. For producer finishers dam breed was also recorded. The farmer confirmed that the animals had been suckled for 5 months. The actions completed on the initial visit were as follows:

- Logging cattle onto the Scheme.
- Checking cattle and facilities met trial needs and enhanced protocol.
- Estimating initial live weight and checking that the target slaughter weights and dates were consistent with trial weight, fatness and conformation specification. The trials officer set a slaughter date deadline beyond which remaining live cattle on the trial would no longer be acceptable due to too low a rate of finishing.
- Checking that the diet would give sufficient daily live weight gain to meet the target slaughter weights and dates. This involved collecting data on the amounts of feed consumed with samples of forages taken for analysis. This diet information was passed to an SAC nutritionist who used the SAC Feedbyte rationing service to confirm that the minimum daily liveweight gain targets set for the combination of breed and sex of animal could be achieved. (Results are summarised in Table 1, Appendix II. All diets submitted met minimum growth rate criteria in the finishing period. Minimum target gains for high eating quality were from 0.7 to 0.9 kg day^{-1} depending on breed and sex, and the Feedbyte predictions of gains for all groups exceeded this by 0.05 to 0.4 kg day^{-1}). The farmer subsequently received a written confirmation of predicted daily gain and confirmation that the animals were on the enhanced protocol. The participating farmer agreed not to make major changes to the feeding regime in the finishing period.

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

- The haulier had been advised of stock number, collection point and agreed date/time.

- Stock had not been physically exercised to exhaustion in the previous 3 days.
- Stock on grass had been off feed for a minimum of 2 hours prior to despatch.
- Housed stock had their last forage feed the night before despatch.
- Electric goads, sticks, alkathene pipes or other blunt hard objects were not used to move stock.
- Groups of cattle previously separated, and horned or polled animals, were not mixed together.
- Cattle were presented clean. Where cattle required clipping this was done 3 days before despatch. Cattle experiencing extreme stress at clipping were not despatched. Clipped cattle were kept in separate strawed pens before despatch.
- Once loaded, stock were moved without delay to the abattoir (own transport only)
- All stockpersons/drivers were properly trained and managed (own transport)
- Cattle had complied with the on-farm aspects of the enhanced protocol and achieved minimum fat class 3 (target 4L)

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 could not identify samples matching all of the preferred criteria. As the abattoirs sourced different cattle types from different areas we could not maintain identical distributions of gender and feeding systems across abattoirs. Overall, however, there was sufficient representation within the basal samples of dairy bred animals, young bulls and non-forage based diets to assess the effects of these factors on eating quality.

Slaughter and carcass processing protocols

A diagrammatic representation of the full trial design is shown in Figure 1.

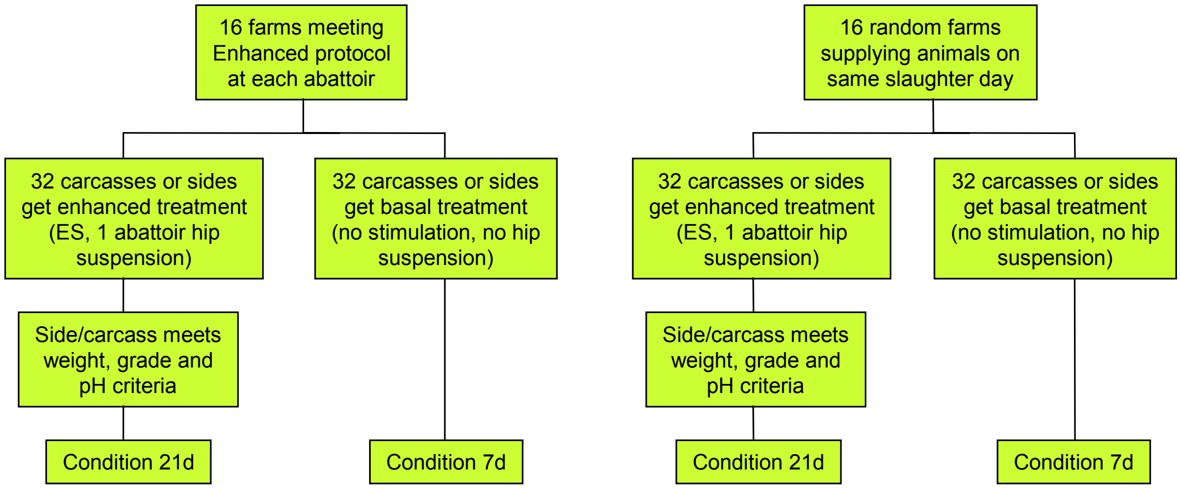
At the abattoir the cattle were received by consortia staff and the following recorded:

- Farmer supplier
- Number of animals dispatched
- 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

These data were collected so that they could be used with carcass data, if necessary, to investigate unusual eating quality results.

Cattle were allowed to rest for one hour then moved forward for slaughter with minimum disturbance.

Figure 1. The trial design indicating the sampling strategy for cattle in each of the two abattoirs



Beef cattle were stunned according to the normal practice for that abattoir. In Plant 1 this was by captive bolt and in Plant 2 by Jarvis electrical stun box. At Plant 1 the carcasses were allowed to proceed through the normal process, but were Achilles hung just prior to the chiller and represented basal processing. From each enhanced farm group, six carcasses, conforming to carcass weight and grade, were identified on the line, three of which were stimulated with low voltage electrical stimulation (LVES) in the bleed trough and hip suspended just prior to moving to the chiller, to act as the enhanced abattoir procedure carcasses. The other three were neither stimulated nor hip suspended and were allowed to proceed along the processing line to act as basal abattoir procedure carcasses. For groups of basal farm animals, the first six animals down the line were identified, three were stimulated and hip suspended, (enhanced processing) and three were not (basal processing).

At Plant 2, carcasses were allowed to proceed through the normal process until the grading station. They had been split into two sides by this stage so it was possible to pick six sides, conforming to carcass weight and grade, from three animals and divert one of each pair onto a side rail. The remaining sides were allowed to proceed through the high voltage electrical stimulation (HVES) unit on their way to the chiller and became enhanced abattoir procedure samples. The diverted sides by-passed the stimulator and proceeded to the chiller and became basal abattoir procedure samples. By using paired sides a more precise comparison of basal and enhanced processing could be made. Basal farm samples were treated in a similar manner.

In Plant 1, 64 animals from the enhanced farm protocol were sampled, 32 received enhanced abattoir treatment and 32 received basal abattoir treatment. An equivalent number of basal animals were sampled. In Plant 2, 64 sides from 32 cattle from the enhanced farm protocol were sampled; one side from each carcass received enhanced and the other basal abattoir treatment. An equivalent design was applied to 64 sides from 32 cattle from the basal farm protocol. Hence, a total of 256 meat samples from 192 animals was involved in this ‘intervention’ study.

In both plants, carcasses were labelled with a blue carcass tag to enable identification in the chiller, where pH was measured in the loin at the 10th rib at 2 hours post-slaughter. At 48 hours post-slaughter pH was re-measured in the sides (carcasses) and two enhanced farm sides (carcasses), which had been subject to enhanced processing, were selected on the basis of grade, weight and pH:

- pH being above 6.00 at 2 hours except in Plant 2 where chilling was more rapid to accommodate the HVES and more rapid pH fall. As sampling was carried out in commercial plants there was no opportunity to alter chilling rates.

- pH not above 5.80 at 48 hours
- minimum fat class 3, conformation class P/O- excluded
- carcass within the weight range of 260-400 kg.

These two sides, together with two enhanced farm sides which had been subjected to basal processing, and four sides from a basal farm, two of which had been subjected to enhanced abattoir processing and two which had not, formed the basis of a group of samples which went forward for sensory evaluation.

Marked sides were taken to the boning hall and a section of loin posterior to the 10th rib was removed. This was a short section for those going for sensory panel alone and a full loin for those that were also assessed by consumers. Samples were vacuum packed with a uniquely numbered laminated sample label inside the bag and sent to Bristol under refrigerated transport within 2 days. At Bristol all basal processed samples were conditioned to 7 days post-slaughter in a chiller at 1ºC. All enhanced processed samples were conditioned to 21 days post-slaughter. At the end of the conditioning period, samples were frozen and stored at –20ºC until sufficient samples had been accumulated for sensory analysis. Frozen loins were bandsawn to give 20 mm loin steaks.

Industry random baseline sample

Only two abattoirs were involved in the intervention study to test the package of enhanced practices. In order to investigate eating quality, and variability in eating quality, across the whole industry, and to compare results with those from enhanced practices, meat samples were obtained from eight additional abattoirs (termed the ‘industry random baseline sample’). The number of samples obtained from each abattoir was in proportion to its contribution to the Scottish beef kill (this ranged from four samples from the smallest to 32 samples from the largest processor). Samples were obtained under the processing conditions normally applied in that abattoir (i.e. there was no ‘intervention’ in this part of the study). Abattoirs were asked what post-slaughter processes they normally practice (electrical stimulation, hip suspension, chilling rate and conditioning time). They were sampled, according to the schedule and the protocol shown in Appendix III, between May and November 2003. When samples arrived in Bristol they were conditioned to a maximum of the period stated by that plant. Where a plant stated that they sold all beef carcasses within 7 days, this was the time used for conditioning. Where a plant stated that they conditioned carcasses from 21-35 days, samples were conditioned for either 21, 28 or 35 days. This produced samples that ranged overall from 7-35 days conditioned.

Some processors do not supply bull beef to the retail steak and joint market whilst others do. The inclusion of bulls in the industry random sample may thus have affected the overall eating quality and steps were taken to investigate this, as described later in this report.

The aim of this part of the study was to investigate beef eating quality, and variability in eating quality, across the Scottish industry, rather than to compare processors. Hence, results have been coded and are presented anonymously, although participants will be made aware of their own code only, if desired. It is important that results for individual plants are interpreted cautiously, especially for smaller plants where, by chance, the small number of samples obtained may not be truly representative.

Sensory panel (trained taste panel)

Cooking

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 cooked, turning every 3 minutes, under the grill of a household Tricity cooker until the internal temperature of the beef, as measured by a hand held thermocouple, reached 74ºC in the geometric centre. The beef 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. These were wrapped in pre-coded aluminium foil and served to individual assessors. As 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 of beef from the same farm, one sample having received basal processing and the other enhanced processing, accompanied by a third sample from the industry baseline group. In the panel immediately following, they received similar samples, but from a basal farm, if the previous panel had been from an enhanced farm, and *vice versa*. Hence, within two panels all four treatment groups within a block had been tested. In the course of a morning eight sessions were run comprising four blocks of two adjacent sessions, i.e. 24 samples per morning with all samples coming from animals killed in the same abattoir on the same day.

Sensory assessment

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 beef was carried out by an adaptation of that for pork as outlined in Wood *et al*, (1995) and Vatansever *et al* (2000)[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),
- beef 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 assessors. The order of sample presentation was structured to reduce the influence of first-order carry over effects.

Consumer testing (take home panel)

Families living in the area surrounding Bristol were asked to take part in the trial. They were told they would receive samples of vacuum-packed frozen beef loin at intervals over a four-week period and that this would be repeated a few months later. In one session the enhanced farm animals were from grass finishing and in the other from silage finishing systems. It was not possible to allocate all samples from basal farms as being either grass-grazed or mainly grass silage-fed, as the diets of the animals were not known in advance. Some silage-fed animals had a high proportion of concentrate in their diet and this was taken into account in the statistical analysis. The families were split into two groups such that one half received meat from Plant 1 and the other group from Plant 2. This arrangement placed more emphasis on a comparison of grass finishing versus finishing on silage-based diets rather than plants. Data were collected on family composition, educational status and the importance (0-10 scale), for each family member separately, of 12 attributes when purchasing and eating meat. Participants were given instructions on how to thaw the beef; basically these were to remove from the freezer 24 hours before cooking and place in a domestic refrigerator. Families were asked to grill the beef as they would normally and serve as part of a meal and to ensure that they used the same cooking procedure over the eight weeks. The person preparing the meat ("Cook") was

[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 Vatansever, L., Enser, M., Nute, G.R, Scollan, N.D., Wood, J.D. and Richardson, R.I. (2000) Shelf life and eating quality of beef from cattle of different breeds given diets differing in *n*-3 polyunsaturated fatty acid composition, Animal Science, 71, 471-482.

asked to answer questions on the Visual and Cooking quality of each sample of meat (0-10 scale). Each family member was asked to complete a questionnaire which contained four, 8 point category scales covering tenderness, juiciness, flavour and overall acceptability, where 1 = dislike extremely to 8 = like extremely. The questionnaire given to each family is shown in Appendix IV.

A total of 48 families, comprising 142 family members, completed the tests. Two families consisted of 5 people, 10 of 4, 20 of 3 and 16 of 2.

The make up of the consumer take-home panel for beef was as follows:

Table 2. The age and gender distribution of panel members

	Gender	
	Male	**Female**
Age (years)		
<25	17	12
25-35	7	5
35-50	28	29
>50	19	22
Total	71	68

Non–respondents 3

Table 3. The educational status of panel members

	Number
School to 16	56
School to 18	37
Graduate	45

Non-respondents 4

Table 4. The frequency of consumption of meat and fish by panel members

	Meat/Fish				
Frequency	**Beef**	**Lamb**	**Pork**	**Chicken**	**Fish**
Weekly	54	20	25	104	51
2-3 times/month	45	51	59	25	41
Once/month	20	38	24	3	19
<once/month	13	19	23	3	16
Never	3	7	4	0	8
Total	135	135	135	135	135

Non-respondents 7

There was a fairly even distribution of males and females (Table 2) and of educational status (which also reflects income) (Table 3). They had a wide range of experiences of eating the different meat types (Table 4).

Family members were asked to rate each of the qualities by which they might choose beef (on a scale of 0-10). Their responses are given in the table below arranged by mean preference score (Table 5).

Safety is obviously still a high priority with consumers when choosing beef. Their next four priorities are all to do with eating satisfaction and could not be used by them for making informed choices at the point of purchase, but may well influence their repeat purchasing habits. They may also have given these a higher rating, as this was an eating quality trial. Colour, visible fat and price are all ranked around the middle of their priorities, but are the factors that would influence their decision at the point of purchase.

Table 5. Mean preference scores for panel members given as their priorities when choosing beef

Quality	Average score
Packaging	3.72
Brand	4.21
Store	5.26
Liquid in cooking	5.73
Liquid in package	5.96
Butcher	6.43
Price	6.65
Marbling fat	7.10
Surrounding fat	7.36
Colour	7.51
Welfare	7.94
Doneness	8.07
Flavour	8.26
Juiciness	8.48
Tenderness	8.64
Safety	8.69

It should be remembered that a trained sensory panel is an uncalibrated instrument, but tests material that is very carefully controlled through preparation, cooking and presentation. They are very good at showing differences between samples, especially those presented to them in one sitting. An experienced panel shows a great deal of consistency over time, though they may score samples differently on different days, especially if the samples are paired with more extreme examples. On the other hand, consumers show appreciation but do not compare samples side by side and there is no control over the consistency in which they prepare samples or how much other family members influence them. Two samples which are extremely tender, but scored as different by a sensory panel, may be equally desirable to a consumer, but if one of those samples were even more tender, the sensory panel would respond in a positive direction, as there scores are 'directional', but the consumer panel may begin to show an adverse response because the sample is now too tender or 'mushy'.

One constraint of take-home panels is that all the family must test the same sub-samples at the same time. Also from a logistical viewpoint, in order to minimise the amount of meat required, and to control the amount of resources required to prepare samples for testing, they must be drawn from as few carcasses as possible. Accordingly, the samples for the take-home panel were drawn from 10 (of 16) kills, six with predominantly silage-fed cattle and four with grass-fed cattle meeting the enhanced specification. Each household received meat from the same abattoir for two runs of four successive weeks. As far as possible, each household received meat from grass-fed cattle in one period and from silage-fed cattle in the other period. Each set of four samples was drawn from a block of the sensory design, one block providing samples for several families.

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. A proportion (50%) of the samples tested together in the blocks of the sensory design were later evaluated by families in the take-home panel.

Taking each of these levels of design in turn:

1. Thirty-two farms, which conformed to the enhanced farm specification, supplied cattle to the two co-operating abattoirs. The cattle were killed on eight occasions at each abattoir between March and December 2003. On each of these occasions, basal cattle of the same gender (where appropriate) were sourced from two farms submitting cattle on that day. Information was collected from the farms on the diet (silage, grass, mainly cereals). As far as possible, basal farms sampled were structured to reflect the normal throughput of each abattoir and included concentrate fed bulls, dairy cross cattle (50% dairy breed minimum) and non forage-based diets in the finishing period.

2. In one abattoir two carcasses were taken from each of the enhanced farms and the basal farms. Carcasses were split; one side was given an enhanced treatment and the other half a basal treatment. At the other abattoir it was not possible to split the sides before processing and so four carcasses were taken from each farm, two being given enhanced processing and two basal processing. Thus from each of 16 kills, sixteen samples were taken - four from each combination of farm protocol and processing.

   One hundred and twenty eight samples to represent the industry random baseline were also drawn from eight further abattoirs in proportion to their annual throughput. Samples from four or eight animals (selected at random from the day's kill) were taken on twenty-two occasions and then given that abattoir's standard treatment.

3. The sensory laboratory evaluated the samples from each kill on different days. Eight industry samples were added to give a total of 24 samples for each sensory day. Three samples were cooked together and served to the sensory assessors at a time. The order of evaluation was determined independently for each assessor so that each sample was evaluated first by one third of the assessors. Each trio consisted of two "experimental" samples plus an industry sample. The two experimental samples had different processing and were from either different sides of the same animal or from two animals from the same farm. Adjacent trios of samples were grouped together into "Blocks" and balanced for the farm specification.

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.

<u>Sensory panel</u>
The presence of industry samples with no simple structure prevented a one-stage analysis being used. Instead the analysis was carried out in two parts.

In the first part sample values were obtained for the 384 samples adjusted for assessor and order of testing. 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:

Assessor + Order (of testing) + Sample

and the Random model:

(Assessor.Day) / Block / Session / Order

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

In the second part the sample values obtained from the first part were analysed further. This analysis was in turn split into two parts the first for the "experimental" samples and the second for the industry samples.

"Experimental" samples

Fixed model:

Abattoir * Processing * Farm Protocol

Random model:

Kill / Farm / Animal

Industry samples

Fixed model:

Abattoir + Gender

Random model:

Kill

By using a two-step process a consistent set of adjustments for assessor and order have been made to the sample values for the "experimental" and industry samples. Thus comparisons between the summaries for the "experimental" and industry samples are free of artefacts of analysis.

Comparison of industry and experimental samples

Fixed model:
Processing + Gender

Random model:
Kill

Take-home panel
As with the sensory data, a model with several random (error) terms, together with fixed terms was fitted using Residual Maximum Likelihood (REML).

The Fixed model was:

Order(of testing) + Abattoir * Processing * Farm Protocol

For both the "Visual and Cooking Quality" and "Eating Quality" data the Random model was:

Tag No. + Sample + Household

Kill + Farm + Tag No.

RESULTS

Summary of data on trial animals

Tables 6-9 and Figures 2 and 3 give details of the distribution of gender, animal weight, conformation, fatness, age and breed-cross type (dairy or beef) of the animals in the experimental groups and industry random group. Carcasses from enhanced farms had to meet the carcass weight, fatness, conformation and pH criteria listed on pages 11 to 12 to be eligible for the trial. A total of 415 animals from farms following the enhanced protocol were delivered in 32 batches to the two plants. Carcasses from 96 of these animals were used in the trial. However, 95% of all animals delivered to one plant and 79% of those delivered to the other met the specified carcass criteria. Those that failed to meet the criteria did so because carcass weights exceeded 400 kg (10 animals in one plant and 33 in the other), because carcass weights were under 260 kg (1 animal in each plant), or because carcasses were below fat class 3 (8 animals in one plant). In most batches that had carcasses falling outwith the criteria, only one or two carcasses per batch were affected. However, in some batches there were insufficient carcasses meeting the criteria, and so carcasses which were marginally outside the criteria had to be chosen to go forward for processing and sensory evaluation. Tables 2 and 3 in Appendix II gave more data on the experimental groups and list samples which did not comply with protocol, and the reasons for this.

Table 6. Distribution of gender between the treatment groups

Farm Protocol	Bull	Heifer	Steer	Total
Basal	20	22	54	96
Enhanced	0	32	64	96
Industry random	21	44	63	128

Table 7. Distribution of carcass weights (kg) between the treatment groups

Farm Protocol	<300	300-350	350-400	400-450	450-500	>500	Total
Basal	20	37	34	4	1	0	96
Enhanced	14	42	36	4	0	0	96
Industry random	47	43	27	5	4	2	128

Table 8. Distribution of conformation between the treatment groups

Farm Protocol	E	U+	U-	R	O+	O-	P+	P-	Total
Basal	0	1	14	59	21	1	0	0	96
Enhanced	0	0	16	77	3	0	0	0	96
Industry random	0	5	14	67	26	8	6	2	128

Table 9. Distribution of carcass fatness between the treatment groups

Farm Protocol	1	2	3	4L	4H	5L	Total
Basal	0	2	15	62	16	1	96
Enhanced	0	0	17	63	15	1	96
Industry random	1	4	21	70	29	1	128

Figure 2. Distribution of conformation between the treatment groups

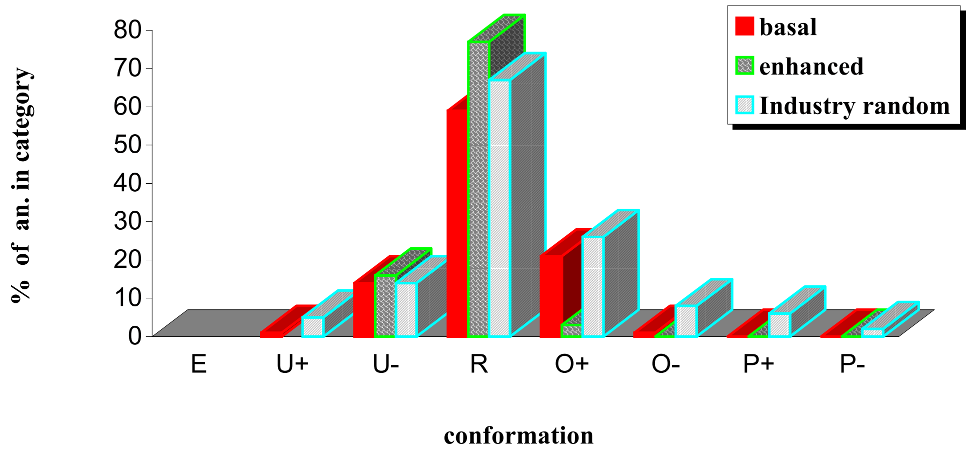
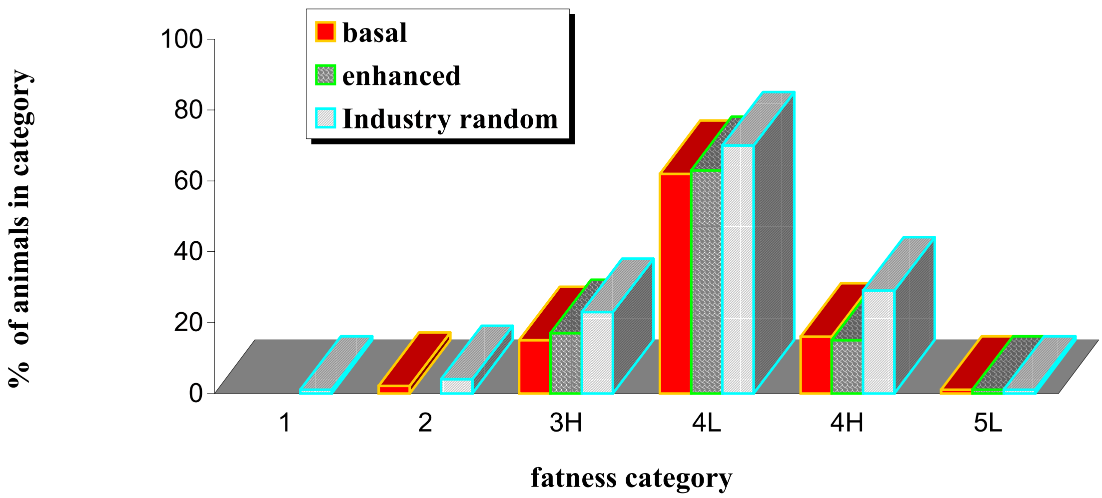


Figure 3. Distribution of carcass fatness between the treatment groups



The distribution of the genders and the carcass data indicate the experimental groups were truly representative of the Scottish beef industry. The numbers of heifers and steers in the basal and enhanced groups were as targeted, whilst the lighter carcasses in the basal and industry random baseline groups probably reflects the number of rapidly finished young bulls. The MLC grading categories show success in production of a tight grouping for conformation in the enhanced animals whilst matching fatness across the basal and enhanced groups so as to avoid confounding influences of fatness on eating quality. The conformation and fatness scores for the industry random samples show that the basal samples were fairly representative of the industry as a whole.

Temperature and pH

Temperature and pH were used to screen carcasses to ensure that they fitted the specifications. A new pH probe was employed which was of metal construction instead of glass, and so is more suitable for use in a food environment. Whilst the probe had been tested before deployment, it was discovered during the trials that it was not suitable for use in beef soon after slaughter when the meat was still at a high pH and very dry and sticky. (Lamb and pork did not seem to pose this problem as the meat was more juicy.) We are confident that the carcasses were screened adequately, that the relevant carcasses were stimulated successfully (confirmed by visual assessment that each stimulated carcass responded to the application of stimulation for the prescribed time), and had a pH generally below that of non-stimulated sides. But the pH values obtained are not sufficiently reliable for statistical analysis. The temperature in the mid loin of the carcasses, measured at the same time as the pH, from both test abattoirs was still above 30ºC at 2 hours post-mortem and was 1.5ºC in both abattoirs at 48 hours post-mortem. All test carcasses were very close to each other in the chiller and, as they were few in number, would have been subjected to very similar chilling regimes, with the only effect on chilling rate being carcass weight and fatness. This would have produced insufficient variation to allow for statistical analysis of the effect of temperature on eating quality. There were no DFD carcasses (pH above 5.8 at 48 hours) - these would not have been admitted under the enhanced protocol, but none occurred in the random baseline-processed animals either.

Tables 10 to 13 show the age, sire and dam breed-type distribution amongst the experimental animals.

Table 10. Distribution of age (days) between the treatment groups

Farm Protocol	<460	460-550	550-640	640-730	730-820	>820	Total
Basal	19	4	10	19	18	26	96
Enhanced	0	2	11	25	44	14	96

Table 11. Distribution of sire breed between the treatment groups

Farm Protocol	British	Continental	Dairy	Total
Basal	13	76	7	96
Enhanced	2	94	0	96

Table 12. Distribution of dam breed between the treatment groups

Farm Protocol	Predominantly British	Predominantly Continental	Dairy	Dairy X	Unknown	Total
Basal	3	47	10	24	12	96
Enhanced	19	54	0	19	4	96

Table 13. Distribution of dam breed (% beef) between the treatment groups

Farm Protocol	0%	50%	75%	100%	Unknown	Total
Basal	10	36	16	34	0	96
Enhanced	0	20	26	44	6	96

The basal group contained a larger number of younger animals than the enhanced group as it contained some young bulls.

Both British and continental beef breeds were represented and all enhanced cattle met the minimum 75% beef target as they had dams with a minimum of 50% beef genes and sires with 100% beef genes. (For those with a dam of unknown classification, the farm assessor decided whether they contained 50% beef genes and should be allowed into the enhanced group.)

Sensory panel and consumer take-home panel results

Enhanced and basal farm and processing effects

Effect of farm protocol

Table 14. The sensory characteristics of beef, assessed by a trained taste panel, according to farm protocol category

	Basal	Enhanced	Sed	Sig.
N	128	128		
Texture (1-8 scale, high = more tender)	4.56	4.59	0.123	ns
Juiciness (1-8 scale, high = more juicy)	4.68	4.74	0.071	ns
Beef flavour (1-8 scale, high = stronger flavour)	3.65	3.72	0.056	ns
Abnormal flavour (1-8 scale, high = stronger flavour)	2.75	2.80	0.047	ns

Sed = standard error of difference; Sig = level of significance
*** = P<0.001; ** = P<0.01; * = P<0.05

Results show no significant changes in the sensory qualities of beef from the application of enhanced practices on farms, in transport and pre-slaughter (Table 14). Whilst there are no statistically significant effects, values for juiciness and beef flavour are close to being significantly different.

The take home panel results (Table 14b) confirm those of the sensory panel. Consumers did not show a preference for either basal or enhanced farm samples. Those responsible for the cooking, ‘cooks’, were able to distinguish that, on average, the enhanced farm samples had a slightly more yellow fat and this may reflect the greater amount of grass-forage in the diet which would contribute carotenoids and hence a yellow colour.

Although there was little effect of pre-slaughter enhanced protocols on the overall mean sensory quality attributes and the take-home consumer panel scores in this trial, this result needs to be interpreted with caution. It is well known from other studies that pre-slaughter factors such as low growth rates (<0.7 – 0.9 kg per day, depending on breed and sex), growth checks, recent diet changes, stressful handling of animals, and the use of bulls, unless these are carefully handled, can reduce meat quality. Basal farms were not deliberately chosen to have contrasting management practices to enhanced farms, but to reflect typical throughput for that abattoir, at that time of year. The fact that no significant effect of pre-slaughter factors was detected here is probably largely due to good practice in the basal farms supplying the participating abattoirs. When the diets on the enhanced farms were analysed at the start of this trial it was found that all Feedbyte predictions of growth rate more than met the minimum rates of growth need for high eating quality. It is likely that the diets from most or all basal farms also complied with these specifications. Also, the design and sample size of the present study was intended to test a package of measures expected to enhance eating quality, not to survey all possible factors affecting quality. Given that pre-slaughter factors are known to affect eating quality, care must be taken to maintain high eating quality standards by following ‘best practice’ on farm.

Table 14b. The sensory characteristics of beef, assessed by a take home panel, according to farm protocol category

	Basal	Enhanced	Sed	Sig.
N	60	60		
Visual and Cooking Quality – Cook				
Size of steak (0-small, 100-big)	61.8	61.4	2.33	Ns
Colour of lean (0-light, 100-dark)	62.2	65.1	1.69	Ns
Colour of fat (0-white, 100-yellow)	50.7	56.6	2.27	*
Amount of surrounding fat (0-small, 100-large)	44.4	46.7	3.04	Ns
Acceptability of amount of surrounding fat (0-unacceptable, 100-acceptable)	59.5	61.4	2.25	Ns
Amount of intra-muscular fat (0-small, 100-large)	44.0	43.1	3.11	Ns
Acceptability of amount of intra-muscular fat (0-unacceptable, 100-acceptable)	60.2	58.8	2.39	Ns
Amount of liquid released in packaging (0-none, 100-very large amount)	46.1	47.7	2.22	Ns
Amount of liquid released whilst cooking (0-small, 100-large)	41.8	43.2	2.02	Ns
Size of steak after cooking (0-small, 100-big)	56.4	55.8	2.00	Ns
Eating Quality – Family				
Tenderness (1-8 scale, high = more likeable)	6.02	6.04	0.203	Ns
Juiciness (1-8 scale, high = more likeable)	6.15	6.14	0.164	Ns
Flavour (1-8 scale, high = more likeable)	6.18	6.18	0.142	Ns
Overall acceptability (1-8 scale, high = more acceptable)	6.09	6.12	0.190	Ns

Effect of processing

Table 15. The sensory characteristics of beef, assessed by a trained taste panel, according to processing category

	Basal	Enhanced	Sed	Sig.
N	128	128		
Texture (1-8 scale, high = more tender)	4.06	5.09	0.077	***
Juiciness (1-8 scale, high = more juicy)	4.75	4.68	0.057	Ns
Beef flavour (1-8 scale, high = stronger flavour)	3.59	3.78	0.036	***
Abnormal flavour (1-8 scale, high = stronger flavour)	2.79	2.76	0.043	Ns

There is a clear and highly significant effect of abattoir processing treatment on the eating quality of the meat, the enhanced treatment producing an increase in rating for texture of over one unit, which is very large in sensory terms. The effect on flavour was an increase of 0.2 units, which is still highly significantly different. There were no significant effects upon juiciness or abnormal flavour.

Table 15b. The carcass and sensory characteristics of beef, assessed by a take home panel, according to processing category

	Basal	Enhanced	Sed	Sig
N	60	60		
Visual and Cooking Quality – Cook				
Size of steak (0-small, 100-big)	62.0	61.1	1.75	ns
Colour of lean (0-light, 100-dark)	64.9	62.4	1.68	ns
Colour of fat (0-white, 100-yellow)	53.8	53.4	1.91	ns
Amount of surrounding fat (0-small, 100-large)	45.9	45.2	2.36	ns
Acceptability of amount of surrounding fat (0-unacceptable, 100-acceptable)	60.7	60.2	2.09	ns
Amount of intra-muscular fat (0-small, 100-large)	43.1	44.0	2.25	ns
Acceptability of amount of intra-muscular fat (0-unacceptable, 100-acceptable)	60.0	59.1	2.18	ns
Amount of liquid released in packaging (0-none, 100-very large amount)	49.5	44.2	2.22	**
Amount of liquid released whilst cooking (0-small, 100-large)	42.1	42.9	2.04	ns
Size of steak after cooking (0-small, 100-big)	56.9	55.3	1.70	ns
Eating Quality – Family				
Tenderness (1-8 scale, high = more likeable)	5.63	6.43	0.144	***
Juiciness (1-8 scale, high = more likeable)	5.89	6.39	0.113	***
Flavour (1-8 scale, high = more likeable)	5.99	6.37	0.122	***
Overall acceptability	5.78	6.43	0.133	***

The take home panel cooks saw a significantly lower amount of purge, or free liquid, in the bags containing enhanced abattoir samples. The families rated the enhanced abattoir processed samples much more highly for texture, juiciness, flavour and overall acceptability than basal processed samples. The biggest differences were for texture and overall acceptability. They showed a preference for the juiciness and flavour of the enhanced samples, though the sensory panel found no difference in juiciness.

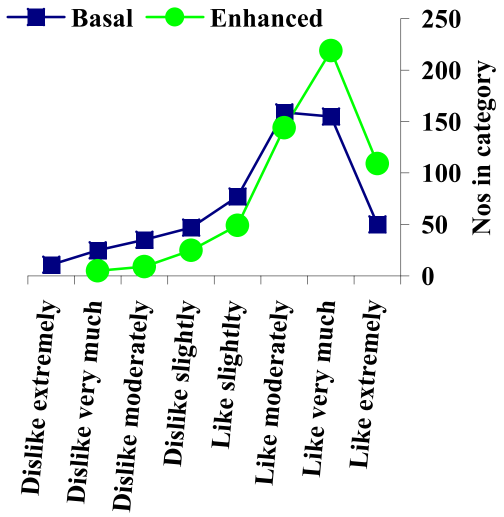
The graphs (Figures 4a to 4d) show that the scores for the enhanced abattoir practices group was pushed approximately one category to the right towards more favourable liking categories.

1. Each attribute shows a very similar distribution suggesting that take home panels are less discriminatory than trained sensory panellists and are influenced by one attribute to score other attributes at a similar level.

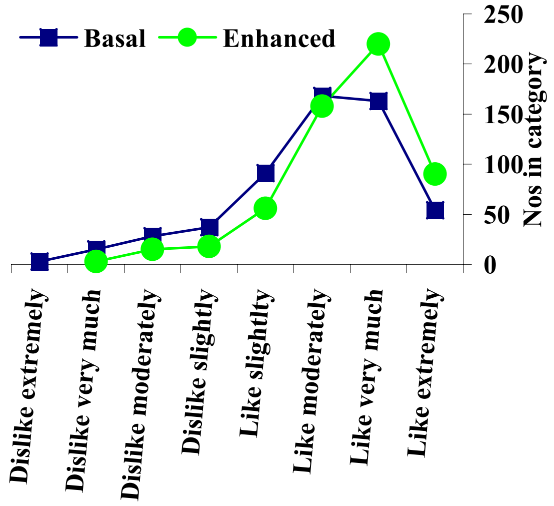
2. Some take home panellists did not like the beef, despite the very high rating given by other consumers.

Figure 4 a-d. Distribution of individual consumer scores for Texture, Juiciness, Flavour and Overall Acceptability by Abattoir Processing category and by category score

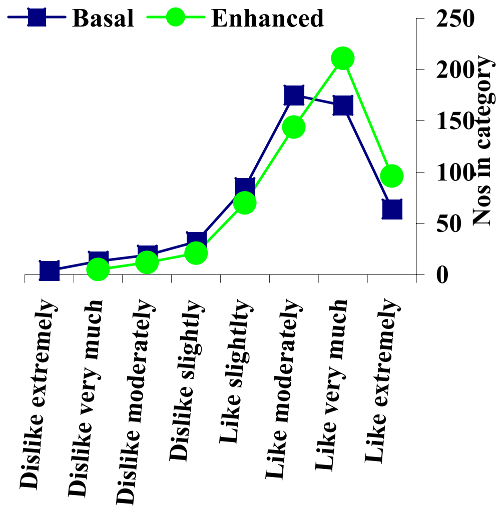
a) Texture



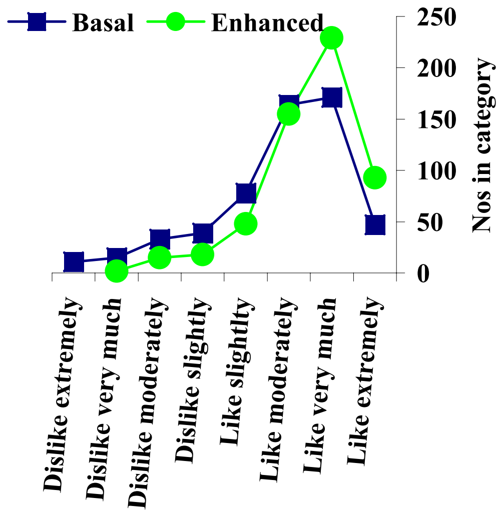
b) Juiciness



c) Flavour



d) Overall liking



Farm and processing treatments/interactions

There were no significant interactions when both farm and abattoir processing treatments were included in the analysis of sensory panel results, i.e. both abattoir sets of meat behaved in the same manner, regardless of farm of origin, with enhanced processing increasing tenderness and flavour (Table 16).

Table 16. The sensory characteristics of beef, 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	64	64	64	64		
Texture	4.10	5.02	4.03	5.15	0.131	ns
Juiciness	4.75	4.61	4.75	4.74	0.088	ns
Beef flavour	3.56	3.74	3.62	3.82	0.061	ns
Abnormal flavour	2.72	2.78	2.85	2.75	0.063	ns

Table 16b. The sensory characteristics of beef, assessed by a take home panel, according to farm protocol and processing categories

Farm Protocol	**Basal**		**Enhanced**		**Sed**	**Sig.**
Processing	**Basal**	**Enhanced**	**Basal**	**Enhanced**		**Int**
N	30	30	30	30		
Visual and Cooking Quality – Cook						
Size of steak (0-small, 100-big)	62.9	60.7	61.1	61.6	2.86	ns
Colour of lean (0-light, 100-dark)	63.7	60.7	66.2	64.1	2.44	ns
Colour of fat (0-white, 100-yellow)	52.2	49.1	55.4	57.7	3.00	ns
Amount of surrounding fat (0-small, 100-large)	45.8	43.0	45.9	47.5	3.81	ns
Acceptability of amount of surrounding fat (0-unacceptable, 100-acceptable)	58.7	60.3	62.7	60.1	3.16	ns
Amount of intra-muscular fat (0-small, 100-large)	43.9	44.0	42.4	43.9	3.75	ns
Acceptability of amount of intra-muscular fat (0-unacceptable, 100-acceptable)	60.7	59.7	59.2	58.4	3.32	ns
Amount of liquid released in packaging (0-none, 100-very large amount)	47.4	44.7	51.6	43.8	3.26	ns
Amount of liquid released whilst cooking (0-small, 100-large)	42.1	41.5	42.1	44.3	2.97	ns
Size of steak after cooking (0-small, 100-big)	57.1	55.8	56.7	54.9	2.67	ns
Eating Quality – Family						
Tenderness (1-8 scale, high = more likeable)	5.60	6.45	5.66	6.42	0.237	ns
Juiciness (1-8 scale, high = more likeable)	5.94	6.35	5.84	6.43	0.190	ns
Flavour (1-8 scale, high = more likeable)	6.03	6.32	5.95	6.42	0.187	ns
Overall acceptability	5.78	6.40	5.77	6.46	0.220	ns

There were no interactions between samples as judged by the take-home panel; hence, enhanced processed samples showed a similar amount of improvement whether the carcasses came from enhanced or basal farms (Table 16b).

Effect of plant (and/or different methods of electrical stimulation)

Table 17. The sensory characteristics of beef, assessed by a trained taste panel, according to plant and processing categories.

	Plant 1		**Plant 2**		**Sed**	**Sig.**	
Processing	**Basal**	**Enhanced**	**Basal**	**Enhanced**		**Plant**	**Interaction**
N	64	64	64	64			
Texture	3.95[a]	5.25[b]	4.18[a]	4.92[b]	0.178	ns	***
Juiciness	4.62[a]	4.42[a]	4.88[b]	4.93[b]	0.100	***	*
Beef flavour	3.55	3.76	3.64	3.80	0.077	ns	ns
Abnormal flavour	2.72	2.74	2.85	2.79	0.111	ns	ns

There is an interaction for texture indicating that the samples in the two plants reacted differently to the enhanced processing (two different forms of electrical stimulation). Whilst the ultimate texture of the enhanced processed samples did not differ significantly between plants, those from Plant 1 started at a lower baseline and hence improved more. Hence, the two different processing procedures at the two plants resulted in the same improved tenderness. Conversely, samples from Plant 2 were juicier than those from Plant 1 overall, despite the latter carcasses being one grade fatter on average. There was an interaction with processing as samples from Plant 2 became juicier with enhanced processing whilst those from Plant 1 became less juicy. This relationship has not been seen before and is difficult to explain. Samples behaved in a similar manner at both plants for beef and abnormal flavours.

The results for the take home panel should be interpreted with caution (Table 17b). The experimental design was such that families received samples from either Plant 1 or Plant 2 so that they could compare processing and season of production within plant. The comparison between plants is thus an imprecise one. However, they did not show the difference in juiciness seen by the trained taste panel, giving support to the theory that a consumer panel is more influenced by tenderness and tends to mark other attributes in a similar manner. Thus tenderness improved in samples from both plants and the take home panel rated juiciness improvements in a similar manner.

Table 17b. The sensory characteristics of beef, assessed by a take home panel, according to plant and processing categories

Plant	Plant 1		Plant 2		Sed	Sig.	
Processing	**Basal**	**Enhanced**	**Basal**	**Enhanced**		**Plant**	**Int.**
N	36	36	24	24			
Visual and Cooking Quality – Cook							
Size of steak (0-small, 100-big)	60.3	58.9	63.7	63.3	3.13	ns	ns
Colour of lean (0-light, 100-dark)	63.7	63.8	66.1	61.0	2.75	ns	ns
Colour of fat (0-white, 100-yellow)	53.3	51.3	54.4	55.5	3.22	ns	ns
Amount of surrounding fat (0-small, 100-large)	43.6	43.2	48.2	47.2	3.76	ns	ns
Acceptability of amount of surrounding fat (0-unacceptable, 100-acceptable)	61.4	62.9	60.0	57.5	3.41	ns	ns
Amount of intra-muscular fat (0-small, 100-large)	44.2	44.0	42.0	43.9	4.01	ns	ns
Acceptability of amount of intra-muscular fat (0-unacceptable, 100-acceptable)	59.7	61.5	60.3	56.6	3.60	ns	ns
Amount of liquid released in packaging (0-none, 100-very large amount)	52.1	43.4	47.0	45.1	3.68	ns	ns
Amount of liquid released whilst cooking (0-small, 100-large)	43.4	44.4	40.8	41.4	3.30	ns	ns
Size of steak after cooking (0-small, 100-big)	57.9	52.6	55.9	58.1	3.08	ns	*
Eating Quality – Family							
Tenderness (1-8 scale, high = more likeable)	5.74	6.51	5.53	6.36	0.259	ns	ns
Juiciness (1-8 scale, high = more likeable)	5.88	6.40	5.91	6.38	0.216	ns	ns
Flavour (1-8 scale, high = more likeable)	5.98	6.37	6.00	6.37	0.212	ns	ns
Overall acceptability	5.79	6.42	5.76	6.43	0.245	ns	ns

Effects of gender, diet and breed

The opportunity was taken to explore the influence of gender (bull, heifer or steer), diet (cereals/concentrates, grass or silage) and breed on the eating quality data from the trained taste panel and on the take home panel data. It was not possible to include the industry animals in the analysis of trained tasted panel data since information on diet and breed was not available for these animals. Data were only collected from the take-home consumer panel for a subset of the samples.

The statistical models used for the trained sensory panel data reported in Tables 14, 15, 16, and 17 and for the take home panel data reported in Tables 14b, 15b, 16b and 17b were augmented by adding terms for Gender, Diet and Breed group to the fixed model.

There were comparatively few samples in these data sets with dairy dams so the data have only limited ability to quantify the magnitude of any differences. It is therefore not surprising that no statistically significant results were found for this factor. The breed term was accordingly dropped from the model. The results for the other two factors are given below. Caution needs to be adopted in interpreting these results since levels of both gender and diet will be associated with packages of other practices. For example, the bulls will be younger and lighter and so differences may be due in part to these factors rather than the fact they are bulls as opposed to steers or heifers. Similarly the comparison between diets is confounded by the fact that only the concentrate diet included bulls.

Table 18. The sensory characteristics of beef, assessed by a trained taste panel, according to gender category – enhanced and basal processing

	Bull	Heifer	Steer	Av Sed	Sig.	
N	28	72	156			
Texture (1-8 scale, high = more tender)	4.23	4.64	4.61	0.244	0.146	ns
Juiciness (1-8 scale, high = more juicy)	4.63	4.67	4.76	0.138	0.576	ns
Beef flavour (1-8 scale, high = stronger flavour)	3.45[a]	3.66[ab]	3.73[b]	0.107	0.023	*
Abnormal flavour (1-8 scale, high = stronger flavour)	2.92	2.79	2.75	0.106	0.335	ns

There was clearly no significant effect of gender within the experimental group of animals (Table 18) as rated by the trained sensory panel except for flavour. Bulls can produce tougher meat, but if grown rapidly and slaughtered comparatively young they will produce meat of acceptable tenderness. The fact that the meat was from young animals and animals grown on high cereal diets may explain why it was less flavoursome.

The take-home panel found few eating quality preferences between genders, but there were some differences in appearance (Table 18b). Steaks from bulls were largest and had the least fat around the steak. The fat and lean of the bulls was also lighter, reflecting the predominantly cereal diet on which they are raised. These differences did not affect their visual acceptability. The fact that steers had more fat around their steaks did not significantly affect eating quality. There was an overall trend for the steer meat to be liked more for tenderness, juiciness and flavour and with highest overall acceptability, with bulls least and heifers intermediate, though none of the values were statistically significantly different.

Table 18b. The sensory characteristics of beef, assessed by a take home panel, according to gender category – subset of enhanced and basal samples

	Bull	Heifer	Steer	Av Sed	Sig.	
N	16	48	56			
Visual and Cooking Quality – Cook						
Size of steak (0-small, 100-big)	66.0	63.0	61.6	4.01	0.005	**
Colour of lean (0-light, 100-dark)	58.4	63.1	65.8	3.30	0.032	*
Colour of fat (0-white, 100-yellow)	45.3	54.7	56.1	4.19	0.068	ns
Amount of Surrounding fat (0-small, 100-large)	35.9	46.2	47.6	4.87	0.049	*
Acceptability of amount of surrounding fat (0-unacceptable, 100-acceptable)	69.7	59.8	57.3	4.17	0.026	*
Amount of intra-muscular fat (0-small, 100-large)	31.8	41.7	50.7	5.38	0.012	*
Acceptability of amount of intra-muscular fat (0-unacceptable, 100-acceptable)	65.9	58.7	59.2	4.58	0.160	ns
Amount of liquid released in packaging (0-none, 100-very large amount)	50.6	47.3	45.6	4.44	0.516	ns
Amount of liquid released whilst cooking (0-small, 100-large)	41.2	42.2	42.7	4.08	0.850	ns
Size of steak after cooking (0-small, 100-big)	59.3	59.3	56.1	3.46	0.471	ns
Eating Quality – Family						
Tenderness (1-8 scale, high = more likeable)	5.67	5.90	6.24	0.364	0.272	ns
Juiciness (1-8 scale, high = more likeable)	5.82	5.95	6.45	0.293	0.154	ns
Flavour (1-8 scale, high = more likeable)	5.84	6.00	6.43	0.265	0.052	ns
Overall acceptability	5.68	5.96	6.34	0.340	0.150	ns

The trained sensory panel did not detect any differences between samples produced from animals raised on different diets (Table 19). There was a tendency for the grass-finished animals to be slightly more tender, meat from cereal-finished animals to be slightly juicier with meat from grass- and silage-finished animals having a slightly stronger flavour.

The take-home panel scored the steaks from grass-finished animals as being significantly smaller and this carried through to the cooked steak (Table 19b). Cereal-finished animals produced less fat around the steaks. These results may be a consequence of the bulls in the cereal-fed group. The least purge in the packaging was found with steaks from silage-fed animals. There was no significant effect of diet on texture although the silage-finished animals had the largest numerical value for texture liking. Grass-finished animals produced steaks which were preferred least for juiciness, whilst silage-finished steaks were preferred most for flavour.

Table 19. The sensory characteristics of beef, assessed by a trained taste panel, according to diet category – enhanced and basal samples

	Cereal/Conc	Grass	Silage	Sed	Sig.	
N	64	96	96			
Texture (1-8 scale, high = more tender)	4.42	4.63	4.43	0.247	0.551	ns
Juiciness (1-8 scale, high = more juicy)	4.79	4.65	4.62	0.142	0.574	ns
Beef flavour (1-8 scale, high = stronger flavour)	3.58	3.62	3.66	0.108	0.761	ns
Abnormal flavour (1-8 scale, high = stronger flavour)	2.84	2.87	2.76	0.108	0.412	ns

Table 19b. The sensory characteristics of beef, assessed by a take home panel, according to diet category– subset of enhanced and basal samples

	Cereal/Conc	Grass	Silage	Sed	Sig.	
N	24	56	40			
Visual and Cooking Quality – Cook						
Size of steak (0-small, 100-big)	68.9	57.4	64.4	4.66	0.019	*
Colour of lean (0-light, 100-dark)	64.0	62.7	60.4	3.84	0.498	ns
Colour of fat (0-white, 100-yellow)	56.7	51.0	48.4	4.89	0.291	ns
Amount of surrounding fat (0-small, 100-large)	38.8	40.7	50.1	5.85	0.015	*
Acceptability of amount of surrounding fat (0-unacceptable, 100-acceptable)	56.5	63.3	66.9	4.85	0.118	ns
Amount of intra-muscular fat (0-small, 100-large)	45.0	35.8	43.3	6.30	0.110	ns
Acceptability of amount of intra-muscular fat (0-unacceptable, 100-acceptable)	62.2	59.8	61.8	5.34	0.813	ns
Amount of liquid released in packaging (0-none, 100-very large amount)	50.6	50.2	42.7	5.11	0.038	*
Amount of liquid released whilst cooking (0-small, 100-large)	40.9	42.5	42.6	4.79	0.952	ns
Size of steak after cooking (0-small, 100-big)	67.0	51.3	56.3	3.99	0.004	***
Eating Quality – Family						
Tenderness (1-8 scale, high = more likeable)	5.74	5.80	6.28	0.428	0.112	ns
Juiciness (1-8 scale, high = more likeable)	6.03[a]	5.81[a]	6.38[b]	0.341	0.013	*
Flavour (1-8 scale, high = more likeable)	5.93[a]	5.94[a]	6.38[b]	0.310	0.040	*
Overall acceptability	5.79	5.84	6.35	0.399	0.059	ns

There were no significant effects of bulls on taste panel results or overall acceptability in consumer tests, however steaks from steers were slightly more juicy and of more likeable flavour. Similarly there were no significant effects of whether cattle were finished off diets consisting mainly of grass, silage or cereals/concentrates on taste panel results or overall acceptability in consumer tests, however steaks from silage-fed animals were slightly more juicy and of more likeable flavour.

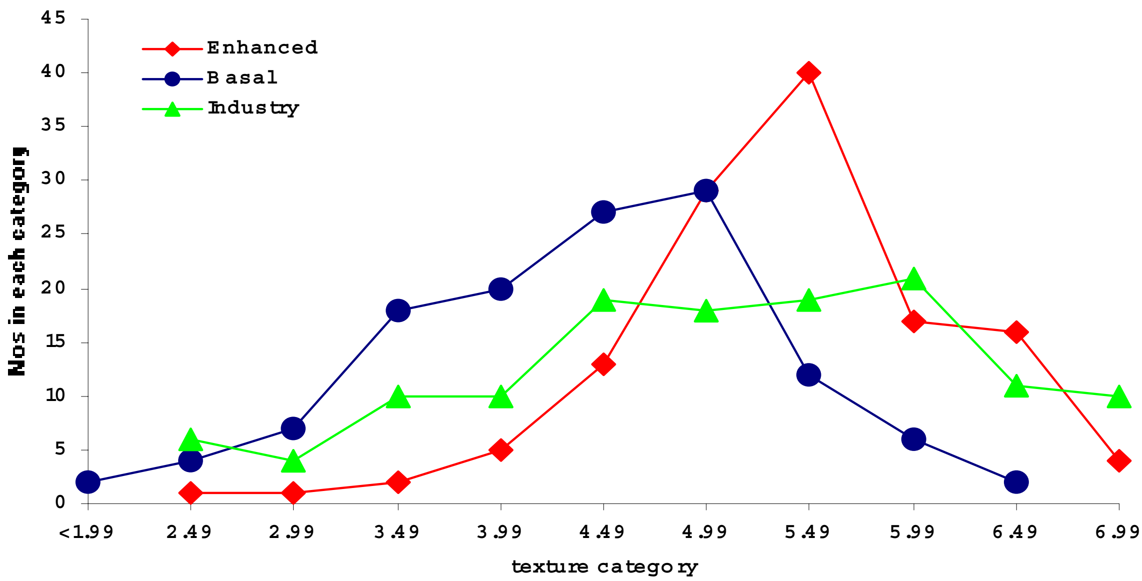
Industry random baseline samples

The purpose of taking industry random baseline samples was to provide a snapshot of eating quality across the industry, from a wider sample than the two abattoirs taking part in the testing of enhanced practices. The industry random baseline samples represented a wide variety of quality ranging from some of the best to some of the worst sampled in this trial. The average industry random baseline values for texture are between those for the basal and the enhanced processed samples (Table 20). Numerically at a value of 4.7, the industry random baseline samples are, on average, less tender than the experimental enhanced processed samples, which had a value of 5, but these values were not statistically significantly different. They are very similar to the basal samples in flavour and statistically inferior to the enhanced processed samples and have significantly more abnormal flavour than either the basal or the enhanced processed samples.

Table 20. Comparison of sensory panel attributes across basal processing, enhanced processing and industry random baseline samples adjusted for differences in gender

	Processing				
Attribute	**Basal**	**Enhanced**	**Industry**	**Sed**	**Sig**
N	128	128	128		
Texture (1-8 scale, high = more tender)	4.00[a]	5.02[b]	4.71[b]	0.171	***
Juiciness (1-8 scale, high = more juicy)	4.71	4.64	4.63	0.100	ns
Beef flavour (1-8 scale, high = stronger flavour)	3.54 [a]	3.73 [b]	3.55 [a]	0.068	***
Abnormal flavour (1-8 scale, high = stronger flavour)	2.83 [a]	2.81 [a]	3.09 [b]	0.086	*

Figure 5. The distribution of taste panel texture values within the basal processed, enhanced processed and industry random baseline samples



It can be seen from Figure 5 that the enhanced processed samples had a distinct cluster around a texture value of 5.5, slightly to moderately tender, rapidly falling away with a long tail of a few samples on the tougher side and a short tail with many more samples on the more tender side. Over

60% of the enhanced processed samples were slightly tender or better. In contrast, the basal processed samples peaked around 4.99 (slightly tender) with only 16% of samples being at or above this value, most being on the long tail to the tougher side of this peak. The industry random baseline samples covered the whole range from extremely tender to very tough, with a fairly even distribution, but still with over 48% being slightly tender or better.

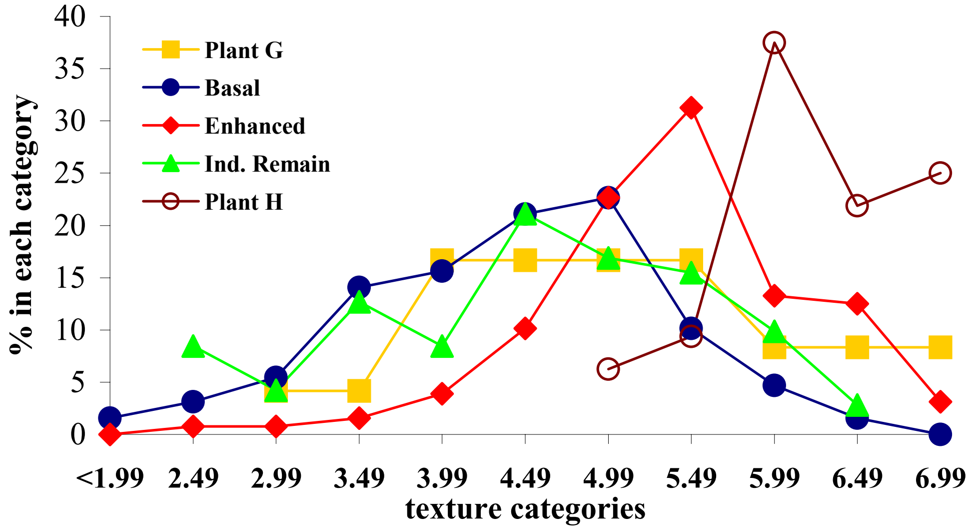
Post slaughter procedures to optimise eating quality declared as being used by the plants in the industry random baseline are shown in Table 21. The conditioning period specified by the plant was implemented before the samples were submitted to the sensory panel. Some plants were allocated more than one conditioning time in order to cover what they practiced and to obtain a representative range of samples for sensory assessment. The results for the plants have been sorted according to the mean texture score recorded for their samples by the trained sensory panel (toughest first). They were then allocated a code for anonymity.

Table 21. Processing conditions associated with toughness in industry samples (A=Toughest, H= Most tender)

Code	Days conditioned (approx)	Enhanced process declared as used for this trial
A	14 & 21	Slow chill
B	28	Slow chill
C	10	Occasional hip, probably not our trial
D	10	Moderate chill
E	7 & 14	Nothing
F	14 & 21	None, immediate chill
G	7	LVES + hip suspension
H	21 - 35	LVES, hip suspension, slow chill, condition

The most tender industry random baseline samples came from two plants and these are shown plotted separately from the rest of the industry random baseline samples in Figure 6. The remainder of the industry random baseline samples are now distributed in a similar fashion to those in the basal processing group. Plant G (LVES and short conditioning) has a very wide distribution across all texture ranges, but Plant H (LVES/HS and long conditioning) has values very much at the very tender end of the scale. The majority of these samples were conditioned for 28-35 days as opposed to the enhanced samples which were only conditioned for 21 days. A further 14 days conditioning may well have produced even more tender samples as shown by plant H.

Figure 6. **The distribution (as a percentage of total in each group) of taste panel texture values within the basal processed and enhanced processed samples, the two industry random baseline plants with highest texture values (G and H), and the remaining industry random baseline plants (Ind. Remain).**



The mean scores for sensory attributes for the eight plants are shown in Table 22. As there was an effect of gender on these results (see Table 24), this has been taken into account in the model used to analyse the data further. Hence, the results in the table are adjusted for the gender effect. The two plants singled out above (Plants G and H) had the most tender meat, that from Plant H being significantly more tender than that from Plant G. Juiciness, beef flavour and abnormal flavour scores do not put the plants in the same order as for texture, but there are no statistically significant differences between samples from the different plants for these attributes.

Table 22. **Taste panel scores for industry random baseline samples**

Abattoir Code	Adjusted Texture	Adjusted Juiciness	Adjusted Beef Flavour	Adjusted Abnormal Flavour
A	4.00[a]	4.69	3.64	3.10
B	4.13[a]	4.03	3.02	3.30
C	4.22[a]	4.82	3.45	3.13
D	4.31[a]	5.26	3.82	3.07
E	4.48[a]	4.45	3.52	2.94
F	4.52[a]	4.90	3.74	3.10
G	4.98[b]	4.93	3.30	3.46
H	5.93[c]	4.32	3.80	3.08
Av sed	0.423	0.376	0.255	0.364
Sig	***	ns	ns	ns

[abc] values with different superscripts within a column are significantly different $p<0.05$

When the data was resorted by approximate conditioning time (Table 23), it can be seen that there is no simple relationship between conditioning time and texture. Meat from Plant G, with the shortest conditioning time, was significantly more tender than that from all other plants except Plant H. Meat from Plant B, with one of the longer conditioning times, was tougher than that from many other plants. However, some plants contributed more samples than others and consequently their production is better characterised by the mean.

Table 23. Taste panel scores for industry random baseline samples sorted by approximate conditioning time. The table shows means and variances (var) for the different eating quality attributes.

Abattoir Code	Conditioning Time	Adjusted Texture		Adjusted Juiciness		Adjusted Beef Flavour		Adjusted Abnormal Flavour	
		Mean	Var[1]	Mean	Var[1]	Mean	Var[1]	Mean	Var[1]
G	7	4.98^{b}	1.011	4.93	0.3018	3.30	0.3514	3.46	0.8317
C	10	4.22^{a}	1.139	4.82	0.1598	3.45	0.2319	3.13	0.3666
D	10	4.31^{a}	2.049	5.26	0.0406	3.82	0.2294	3.07	0.4499
E	7 & 14	4.48^{a}	1.046	4.45	0.1806	3.52	0.1410	2.94	0.3292
A	14 & 21	4.00^{a}	0.833	4.69	0.3835	3.64	0.2594	3.10	0.5377
F	14 & 21	4.52^{a}	0.975	4.90	0.2121	3.74	0.1211	3.10	0.2611
B	28	4.13^{a}	1.316	4.03	0.0692	3.02	0.4092	3.30	0.4092
H	21 – 35	5.93^{c}	0.345	4.32	0.2953	3.80	0.1489	3.08	0.3011
Av sed		0.423		0.376		0.255		0.364	
Sig		***		Ns		Ns		Ns	

[abc] values with different superscripts within a column are significantly different $p<0.05$

[1]NB Small numbers of samples were taken from some plants, and so variances in particular are poorly estimated for these. Ratios of variances exceeding 2 correspond to significance at the 5% level approximately

Plant G said they used LVES and hip suspension, but sold their carcasses very quickly and had no control over the amount of subsequent conditioning employed. All samples from this plant were only conditioned for 7 days. Plant H has spent many years fine-tuning a process to produce top quality beef. They also employ LVES, hip suspension and conditioning of up to 35d. Samples from this plant were conditioned for 21, 28 or 35 days. Although they were from different plants, results from all the samples from these two plants were averaged by days conditioned and plotted against texture (Figure 7). These results show that even though LVES/Hip suspension improves texture, conditioning will improve it further. The overall result emphasises the fact that some intervention process such as ES and/or hip suspension is required to ensure the avoidance of toughness and that conditioning alone is insufficient.

This emphasises further why the texture of the experimental, enhanced-processed samples were not as tender as those from Plant H. We only employed 21 days conditioning and 35 days would probably have produced even more tender meat.

The variability in some of the major eating quality characteristics is also shown in Table 23. The variance for texture tended to decrease with increasing conditioning time, but was dramatically decreased in plant H which employed both post-slaughter interventions and prolonged conditioning. Plant G used LVES on some, if not all, samples but these samples were conditioned for the shortest time of all. In some cases variability may have been reduced by other pre-slaughter control/audit measures not investigated here.

Figure 7. The relationship between conditioning time and sensory texture score for two of the industry random baseline plants employing LVES/Hip suspension

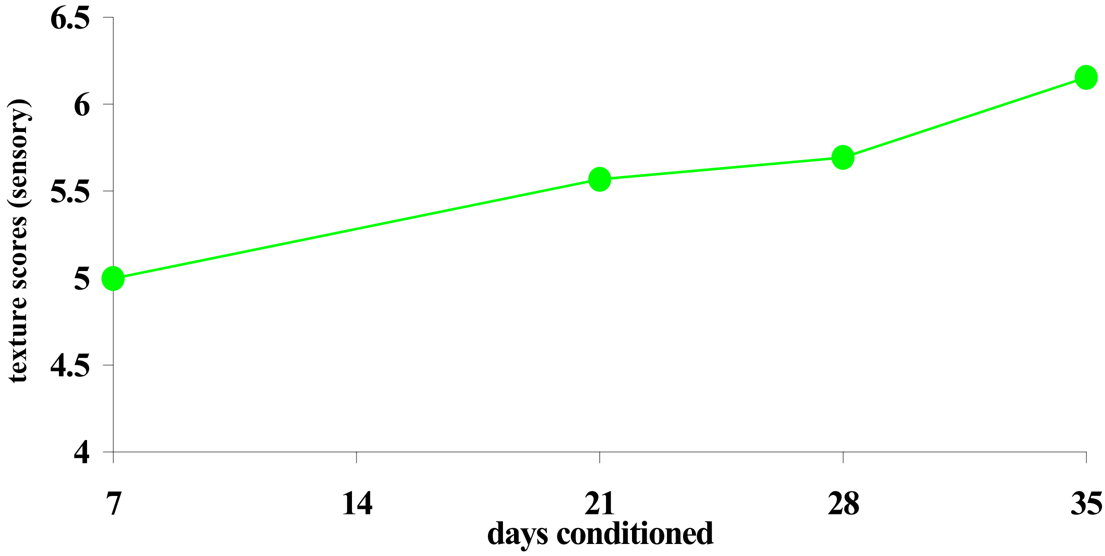


Table 24. The distribution of sensory attributes by gender for industry random baseline adjusted for abattoir

Attribute	Bull	Heifer	Steer	Sed	Sig
Texture (1-8 scale, high = more tender)	21	44	63		
Juiciness (1-8 scale, high = more juicy)	4.32[a]	4.65[b]	4.77[b]	0.148	*
Beef flavour (1-8 scale, high = stronger flavour)	4.59	4.72	4.68	0.090	ns
Abnormal flavour (1-8 scale, high = stronger flavour)	3.45[a]	3.69[b]	3.6[b]	0.067	**
Texture (1-8 scale, high = more tender)	3.03	2.84	2.8	0.084	ns

There was an effect of gender on texture and flavour within the industry baseline group with bulls being slightly less tender and of a lower beef flavour than heifers or steers. This is compounded by the many different processing protocols used across these plants and the fact that plant H contributing the most tender meat did not submit any bull meat. Whilst these effects were not significant for the more controlled basal and enhanced processed animals (Table 18), the trends were the same.

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, matching baseline and industry random 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.) The results are shown in Tables 25 to 28.

Table 25. Variability of samples assessed by the trained taste panel for texture

Processing	Farm Protocol	Variance	25th Percentile	Median	75th Percentile
Basal	Basal	0.790	3.54	4.20	4.75
	Enhanced	0.873	3.40	4.15	4.70
	Basal + Enhanced pooled	0.828	3.48	4.18	4.73
Enhanced	Basal	0.573	4.66	5.05	5.43
	Enhanced	0.581	4.77	5.25	5.71
	Basal + Enhanced pooled	0.580	4.69	5.19	5.58
All industry random baseline		1.337	4.05	4.85	5.63

Table 26. Variability of samples assessed by the trained taste panel for juiciness

Processing	Farm Protocol	Variance	25th Percentile	Median	75th Percentile
Basal	Basal	0.226	4.39	4.80	5.08
	Enhanced	0.296	4.49	4.79	5.20
	Basal + Enhanced pooled	0.259	4.43	4.79	5.15
Enhanced	Basal	0.350	4.19	4.64	5.03
	Enhanced	0.320	4.41	4.86	5.11
	Basal + Enhanced pooled	0.338	4.32	4.75	5.06
All industry random baseline		0.393	4.26	4.68	5.11

Table 27. Variability of samples assessed by the trained taste panel for beef flavour

Processing	Farm Protocol	Variance	25th Percentile	Median	75th Percentile
Basal	Basal	0.119	3.34	3.58	3.88
	Enhanced	0.140	3.38	3.58	3.83
	Basal + Enhanced pooled	0.129	3.35	3.58	3.87
Enhanced	Basal	0.162	3.49	3.77	4.01
	Enhanced	0.120	3.59	3.83	4.06
	Basal + Enhanced pooled	0.141	3.54	3.80	4.03
All industry random baseline		0.273	3.32	3.66	3.94

Table 28. Variability of samples assessed by the trained taste panel for abnormal flavour

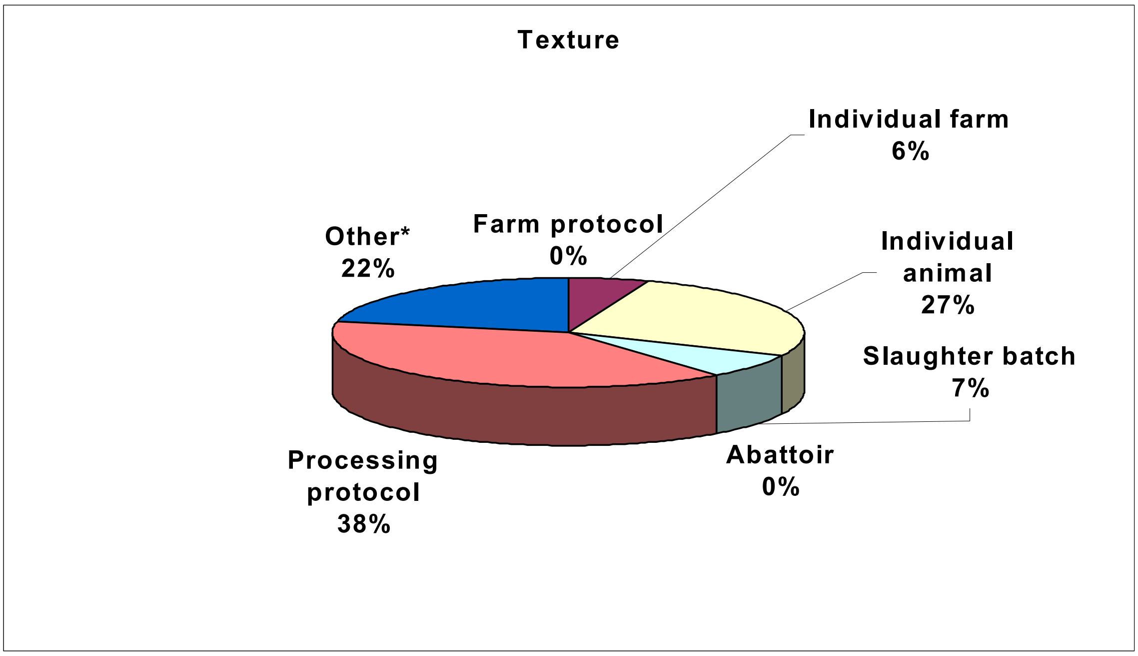
Processing	Farm Protocol	Variance	25th Percentile	Median	75th Percentile
Basal	Basal	0.152	2.44	2.71	2.97
	Enhanced	0.203	2.52	2.81	3.03
	Basal + Enhanced pooled	0.180	2.51	2.73	3.02
Enhanced	Basal	0.192	2.50	2.82	3.02
	Enhanced	0.179	2.41	2.70	2.94
	Basal + Enhanced pooled	0.184	2.44	2.74	3.01
All industry random baseline		0.497	2.53	2.92	3.42

The results show that the variation is always higher for the industry random baseline group – expected to some extent because there are more plants, and hence a wider range of practices involved. For texture, juiciness and beef flavour the 75th percentile of the industry baseline group is comparable to the samples with both enhanced farm and processing practices and for Abnormal Flavour (a negative feature) the 25th percentile is comparable to the enhanced farm, basal processed samples. The differences are in the long tail on the poorer rating side of the median. For texture, where the clearest differences were found, the enhanced abattoir-processing group had the least variance. This effect for texture can also be seen in the long tails to the left in Figure 5. Tables 25 to 28 shows that the variance in texture due to processing was reduced from 0.83 to 0.58, that for juiciness increased from 0.26 to 0.33 and variances were virtually unchanged for flavour and abnormal flavour.

Overview of sources of variation in eating quality

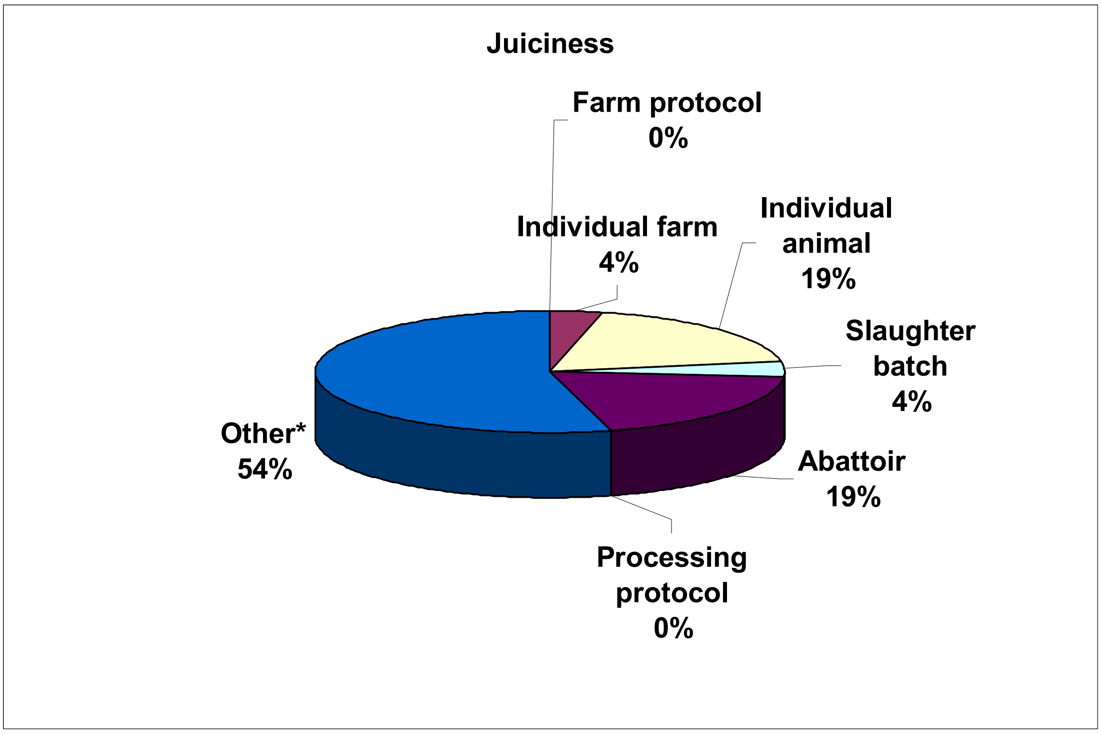
Figures 8 to 11 provide an overview of the main sources of variation in texture, juiciness, flavour and abnormal flavour, as judged by the trained taste panel in the intervention trial (i.e. in two abattoirs only). These results have been obtained with a much simpler statistical model than that fitted 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. As most farms submitted batches of a single sex and a similar breed type, sex and 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. Both pre- and post-slaughter factors were responsible for substantial proportions of the variability in texture, juiciness and tenderness. A fairly high proportion of the variation in abnormal flavour was associated with individual slaughter batch. As discussed above, the enhanced processing protocol was particularly effective in controlling variation in texture, but less so for juiciness and flavour. Substantial proportions of variation are attributable to individual farm and individual animal, although the precise causes of this variation remain poorly understood. They are not, in the main, associated with factors we were attempting to control via the enhanced farm protocol (although 'best practice' may have been applied in both enhanced and basal farms). There is within-breed genetic variation in many meat eating quality characteristics, and this explains some of the individual animal variation. It is notable that 22%, 54%, 39% and 62% of the variation in texture, juiciness, beef 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 commercially applied package of measures expected to improve eating quality, rather than to precisely apportion sources of variation; a tightly controlled experiment might 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 8. Sources of variation in texture, as judged by the trained taste panel, on samples from the intervention trial



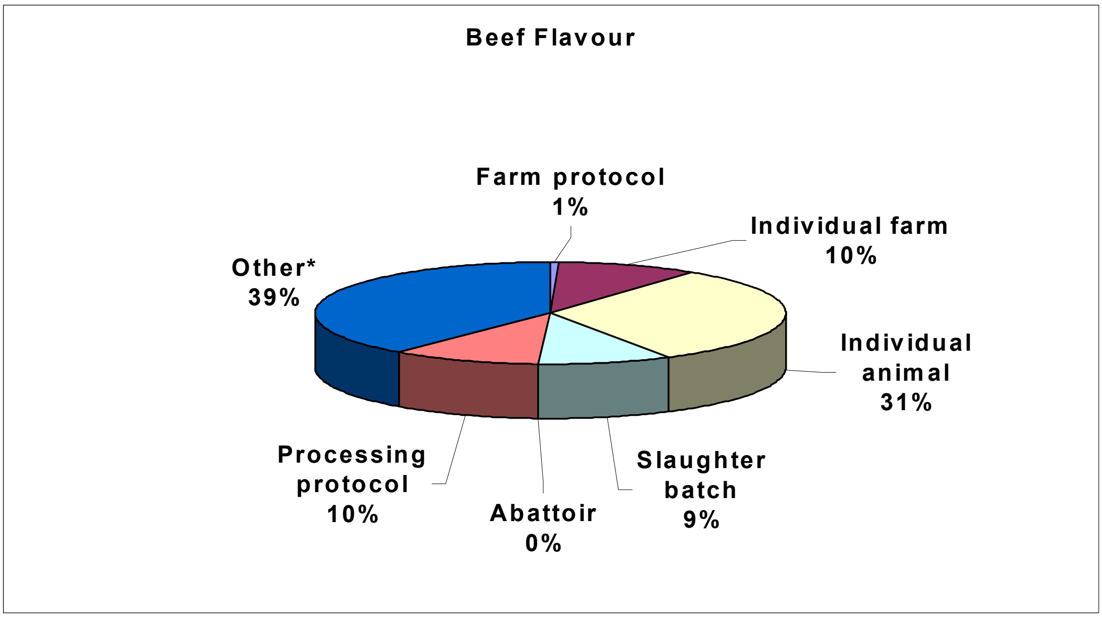
'Other' includes measurement error and the small effects of interactions between processing and farm protocol and processing protocol and abattoir.

Figure 9. Sources of variation in juiciness, as judged by the trained taste panel, on samples from the intervention trial



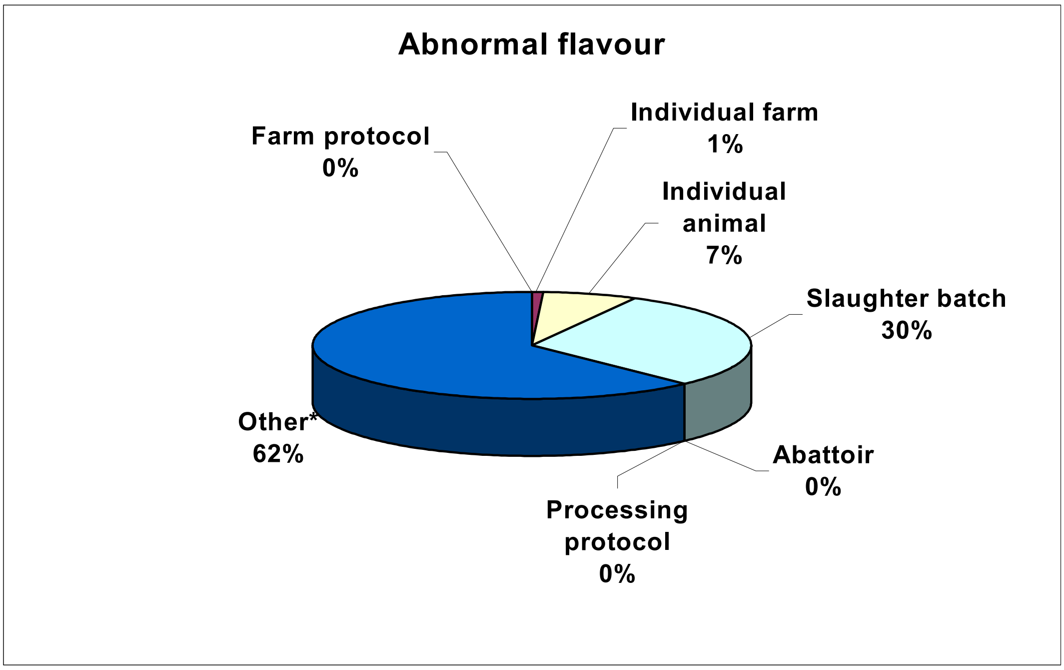
'Other' includes measurement error and the small effects of interactions between processing and farm protocol and processing protocol and abattoir.

Figure 10. 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 farm protocol and processing protocol and abattoir.

Figure 11. 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 farm protocol and processing protocol and abattoir.

CONCLUSIONS

- We were successful in sourcing the number of cattle intended, the vast majority meeting the specifications set.

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

- Consumers rated the beef overall as of good quality, with a score of around 6 on the scale of 1 (dislike extremely) to 8 (like extremely).

- It is well known from other studies that pre-slaughter factors such as low growth rates, growth checks, recent diet changes, stressful handling of animals, and the use of bulls, unless these are carefully handled, can reduce meat quality. In this study, there was no significant effect of the pre-slaughter enhanced protocol on the sensory panel or consumer panel scores, but this result needs to be interpreted with caution. Basal farms were not deliberately chosen to have contrasting management practices to enhanced farms, but 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 largely due to good practice in the basal farms supplying the participating abattoirs. Hence, care must be taken to adhere strictly to ‘best practice’ guidelines for rearing and handling cattle, and to avoid factors such as growth checks and stress, known to negatively affect quality.

- Post-slaughter enhanced processing had a major, positive impact on most attributes of beef eating quality. This was true for both abattoirs and their different means of enhancing the eating quality of meat (high voltage or low voltage electrical stimulation and hip suspension). The consumer panel showed a highly significant preference for the abattoir-enhanced processed samples for texture, juiciness, flavour and overall liking.

- Several pre- and post-slaughter factors were responsible for substantial proportions of the variability in texture, juiciness and tenderness, as judged by the sensory panel in the intervention trial. The enhanced processing protocol was particularly effective in controlling variation in texture, but less so for juiciness and flavour. Also, although substantial proportions of variation are attributable to individual farm and individual animal, the precise causes of this variation remain poorly understood. They are not, in the main, associated with factors we were attempting to control via the enhanced farm protocol. A moderate to high proportion of the variation in texture (22%), juiciness (54%), beef flavour (39%) and abnormal flavour (62%) 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.

- Compared to the industry random sample, enhanced processing produced meat of higher average eating quality (approaching statistical significance) and significantly higher beef flavour, with more consistent texture and flavour.

- The purpose of the industry random sample was not to directly compare abattoirs, but to provide a representative sample of meat produced under current industry practice. However, there are some trends that are worth highlighting. The abattoirs responsible for most of the more tender samples employed an enhanced processing procedure, with the tenderness of the meat being further enhanced by conditioning. Those plants that employed conditioning without electrical stimulation or hip suspension did not produce meat that was as tender.

- In view of the substantial improvement in eating quality that followed enhanced processing in the abattoir, and the lower eating quality in those industry random samples from abattoirs that relied solely upon conditioning, it would be valuable to further test enhanced processing procedures such as hip suspension and electrical stimulation, alone or in combination with varying conditioning times, so that the industry has a choice of which processes to adopt for its purpose.

- There was evidence from within the industry baseline samples that bulls produced tougher meat than heifers or steers.

APPENDIX I : BEEF PROTOCOL AS SENT TO FARMER PARTICIPANTS

MEAT EATING QUALITY – A WHOLE CHAIN APPROACH

Beef protocol for farmer participants

**SAC/BioSS/University of Bristol/
University of Newcastle/SFQC/QMS**

Project Contacts

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Producer Address

Dear Sir

SAC TRIALS ON ENHANCED EATING QUALITY OF BEEF AND SHEEP

You have indicated interest in the above trial and this letter explains how it will operate.

The Trial has a two-part process – a visit by the trial organiser to set up the group which will provide meat for sensory analysis and collect data and directions on how the animals are to be handled prior to despatch and the data to be collected at this time .

Trial organiser visit - purpose:

- To log cattle onto the Scheme.
- To check cattle and facilities meet Trial needs.
- To check initial live weight (weigh cattle)and check the target slaughter weights and dates are consistent with a high eating quality product and the trial sampling dates. The organiser will set a slaughter date deadline beyond which remaining live cattle on the trial will no longer be acceptable due to too low a rate of finishing.
- To check the diet will give sufficient daily live weight gain to meet the target slaughter weights and dates and high eating quality. This will involve collecting data on amounts fed and samples of forages for analyses. If there is evidence that concentrates fed may have unusual feed values these will also be checked .

On leaving the farm a checklist will be filled in by yourself – purpose:

- To ensure cattle leave the farm with high glycogen levels
- To ensure cattle are not stressed during transport
- To ensure cattle arrive in a clean condition at the abattoir

See enclosed pack for details. The trials organiser will go through the procedures to check you are happy with them and can provide the information and requirements.

Trial procedures

1. The trial organiser will download from BCMS your cattle data listed within sex categories in ascending order of date of birth, i.e. youngest first age and display it as shown in the attached spreadsheet example.

2. The trial organiser will allocate on the list the cattle identified for the enhanced specification by adding a group number. To comply for the enhanced group:
    - Steers or heifers as indicated
    - Out of beef suckler cows by a beef sire
    - Have been suckled for at least five months
    - Finished on grass or after a summer on grass on forage and concentrates in-house
    - Growing fast enough in the finishing period

    The trial organiser will collect data from cattle passport to check there are no set-on calves of dairy origin in the group.
    As a guide the group should have dates of birth within a 3 month period at most and no more than 75kg difference between the heaviest and lightest.

3. It will be necessary to weigh the cattle in the group and record condition score.

4. The trial organiser will collect data in a list of feeds fed showing the fresh amounts offered per day and collect samples for feed analysis by SAC. An SAC nutritionist will check diets meet requirements for minimum rates of gain consistent with high eating quality according to breed and sex (see attached feeding protocol). For your information, the minimum target daily gains (kg/d) will be:

	Steer	**Heifer**
Continental	0.9	0.8
British	0.8	0.7

5. The trial organiser together with you will use previous knowledge to estimate the target slaughter dates and weights for cattle and make abattoir arrangements for sampling.

6. **During the visit:**
   1. The trial organiser will confirm your animals meet trial requirements .
   2. The trial organiser will indicate a deadline date and minimum carcass weight by which the animals should have finished. After this date, all remaining live cattle are off the trial. Note the daily live weight gain requirements for meeting high eating quality standards are <u>not high</u> – towards the bottom end of commercially achieved ranges and only animals suffering a severe setback likely to affect eating quality are unlikely to meet the targets.
   3. The trial organiser will leave you with a copy summarising all the information relevant to the batch of animals on the trial.

   After the visit: The abattoir will get a copy of the data for planning and to ensure they are prepared for the target slaughter dates.

   1. Ensure the cattle are maintained on the diet plan. No major changes to be made prior to slaughter but adjustment to the concentrate levels to meet targets are OK, inform the trials organiser.
   2. Fill in the self-assessment checklist prior to moving stock to slaughter.

Thank you for your help it is much appreciated I'm sure you will be as interested as us in how the animals you provide rate in the eating quality assessments.

Standard data collection SAC trial Beef [Housed]

Stage 1 Documentation (copy to farmer, copy to abattoir)

Date of visit:
Consignment Abattoir:
Farmer's Name:
Farm Address:

Identify cattle logged onto scheme:(see BCMS data sheet and add Group No. - as in spreadsheet example)

Summary data

Month of birth:
Month of weaning :
Check birth to weaning is more than 5 months ………………
Breed of sire ………………..Breed of cow …………………….Steers……….Heifers…….

Target slaughter (finishing) period Start………………………Finish………………
Target slaughter weight (kg)
Check start date more than 3 months from visit date ………….
Check daily gain during finishing period is above minimum required…………
Check diet will achieve growth rate target ………………..
Date by which all cattle must be slaughtered to comply …………………………………..
Carcass wt by which all cattle to be slaughtered to comply …………………………………..*

- Note: to allow for variation and market conditions an allowance of +or –10% in carcass wt up to the date of estimated mean slaughter date is acceptable.

SAC Eating Quality Trial Farm Individual cattle Data Collection (enhanced beef animals)

								EATING QUALITY WINDOW			
Tag No	Date of birth	Date of weaning	Sex	Sire Breed	Dam Breed	Liveweight	Managem ent Tag No.	Target dates slaughter	Target lwt at slaughter	Target slaughter carcass	Current conformat ion score/fat class
	xx/xx/xx	xx/xx/xx									

Trial organisers Guide and Interpretation

Diet over the finishing period

Assess that the diet will achieve growth rates finishing within the optimum eating quality window.

(1) Check the finish is feasible

	Steers or heifers	**Start**	**Finish**
Expected slaughter period			
Expected carcass weight			
calculate finishing weight			Carcass wt ÷ 56 kg (A)=……kg

Using Table 1, identify the minimal target DLWG (kg/d) (B).

Table 1. Recommended minimum rates of daily gain to ensure high eating quality

	Steer	**Heifer**
Continental	0.9	0.8
British	0.8	0.7

From (A) take current liveweight estimate (C) A-C = ……. D kg = kg gain required.

Divide (D) by (B). This gives the number of days from now that it will take to finish the animals if they grow at the minimum target growth rate.

Using a calendar check what this date will be and that it is within the start to finish window.

To estimate the deadline date you must allow for variation within the group so add 50 days for this.

Put this date on the form together with the slaughter weight target.

(2) Check the diet will achieve the beef cattle target growth rate.

A rough estimate can be made using the graph Fig.1 (see example below) but a detailed evaluation will be made by M Lewis using SAC's FeedByte diet formulation program using the forage analysis and the information you have collected on the Feed Data Sheets.

Example of the use of the graph (Figure 1).

1. Estimate the total amount kg of concentrate or equivalent dry matter fed/head/day day over the finishing period.
2. From Fig. 1 read off the minimum level of concentrates required to support the target performance for the type of cattle being fed for a particular forage quality.
3. If this **amount is less that what is being actually fed** then the diet meets the minimum specification for finishing performance as set out in Table 1.

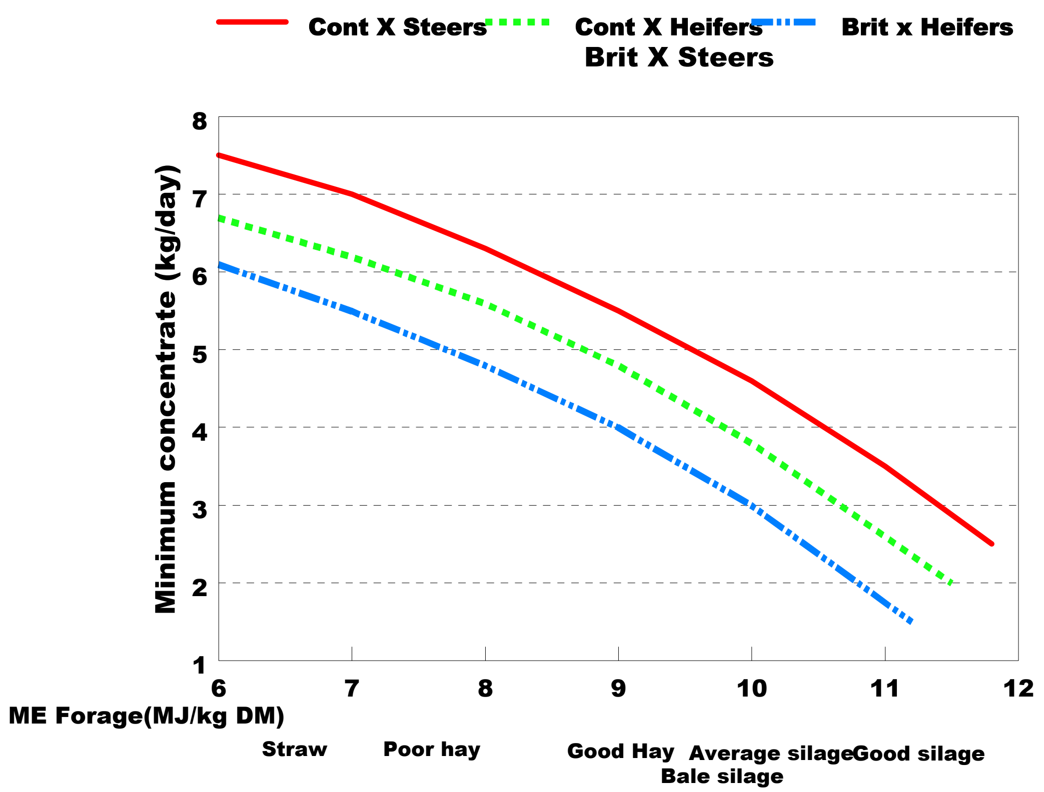
FEED DATA COLLECTION SHEET FOR FORAGES

(1)	(2)
Forage name	Fresh amount fed/day (kg)
TOTAL	

FEED DATA COLLECTION SHEET FOR CONCENTRATES

(1)	(2)	(3)	(4)
Concentrate name	Amount fed/day (kg)	Dry matter content g/kg	Dry matter fed kg/day $\frac{\text{col 2 x col 3}}{1000}$
TOTAL			

Guide to **minimum** concentrate levels, fed with forages of different quality, to achieve target performance over the last three months of finishing



Stage 2 CHECKLIST on dispatch of beef cattle to an abattoir
(copy to accompany cattle to abattoir)

	Tick box	
Haulier advised of stock number, collection point, agreed date/time	□	(1) See accompanying text
Stock not physically exercised to exhaustion in the previous 3 days	□	(2)
Stock on grass to have been off feed for a minimum of 2 hrs prior to despatch	□	(3)
. Housed stock to have last forage feed the night before despatch	□	(4)
Electric goads, sticks, alkathane pipes or other blunt hard objects not to be used to move stock	□	(5)
Groups of cattle previously separated not mixed, no horned or polled animals together	□	(6)
Cattle must be presented clean. Where cattle require clipping this should be done 3 days before despatch .If extreme stress occurs at clipping cattle not to be despatched .Clipped cattle to be kept in separate strawed pen before despatch.	..:..	(7)
Time cattle started loading (use 24 hr clock)	..:..	
Time lorry departed		
Once loaded, stock moved without delay to abattoir (own transport only)	□	(8)
All stockpersons/drivers to be properly trained and managed (own transport)	□	(9)
Cattle have complied with Stage 1 and achieved minimum fat class 3 (target 4L)		

NOTE: This checklist is a useful reminder of the current procedures to ensure the highest possible eating quality of your stock. It is both your safeguard in the event of a follow-up from a customer complaint and a real contribution to a consistent product.

(1) SSSFA approved hauliers to be used only (includes farm transport that has been assessed).

(2) Animals to have high glycogen reserves at dispatch, normally fed animals will have adequate glycogen reserves to see them through a normal (mainland) Scottish transport to abattoir. Glycogen reserves can be depleted by stress, excitement and hard physical exercise, e.g. prolonged (hours) fighting between mixed batches of cattle. This may occur when housed cattle escape and run around fields or when grazed cattle are difficult to get in for sorting and run about for hours. Cattle that get upset may deplete their glycogen reserves through a greater adrenal response (fight or flight reaction to stress), known flighty cattle should be handled differently as they may not settle/eat after handling and take longer to recoup glycogen reserves.

a. Where cattle get exhausted they can recoup their glycogen reserves within 24-48 hours provided that they are given a stress-free environment and access to feeds and water which they are used to, for example with housed cattle putting them back in a pen or with grazed cattle putting them in a grass paddock, preferably handy for the loading area.

   b. A high glycogen reserve in the muscle (leaving the farm with a full bucket) provides the energy source for the development of the correct ultimate pH in the muscle. This is achieved by glycogen breakdown following slaughter to form lactic acid within the muscle ensuring good keeping quality. Residual glycogen (sugar) reserves react with proteins during cooking in Maillard reactions that give the muscle part of meat its 'meaty flavour'. The higher the glycogen reserves the better as this reduces the chance of getting dark cutting meat and gives a haulier/abattoir more flexibility to cope with unprecedented factors such as traffic jams or mechanical breakdowns.

2. Most housed cattle are fed night and morning. The day prior to dispatch sort cattle to go after their morning feed and belly clip them (where necessary), put the group in a separate well-strawed pen with their normal night ration (this will usually be cleared up before midnight) and do not replenish troughs on the morning of dispatch. Known flighty individuals can be handled a couple of days earlier.

   a. For grazed cattle, have them taken off grass to the loading facility a minimum of two hours before transport. Where cattle are brought in overnight, put them in a strawed court prior to dispatch. The objective is to empty the lower gut of faeces so the cattle arrive cleaner. At all times on the farm, the cattle should have access to water. This is a welfare requirement and cutting off water in any case does not help cattle arrive cleaner.

3. The aim is not to stress the animal – best achieved by getting cattle to associate people with being fed. Housed cattle that frequently see humans quieten down. Grazed cattle visited regularly and fed concentrates prior to slaughter are much more easily handled. Do not isolate flighty individuals.

4. Mixing groups that leads to fighting results in low glycogen reserves. Mixing horned and polled cattle creates additional welfare risks.

5. Normal meat hygiene rules apply. Dirty cattle to be belly clipped.

6. This information can be used to sum up the total handling/transport time so that, where appropriate, over-stressed animals can be rested by abattoir staff.

7. To protect welfare and avoid stressing animals, all those responsible for handling and transporting stock should have been trained and management should regularly check for welfare abuse/bad practice.

8. To comply with the Scheme, cattle must be at least fat class 3 (target fat class 4L) and reach conformation grade O+ or better. Also they must be slaughtered before the deadline date and weight. The abattoir will check all these.

APPENDIX II: ANIMAL SPECIFICATIONS AND DATA DEVIATING FROM PROTOCOL

Table 1. Results of Feedbyte predictions of daily liveweight gain (kg) and target liveweight gain consistent with high eating quality.

Kill No	Project Farm No	Farm Protocol	Diet	Target Gain	Predicted Gain (Feedbyte)
1	1003	E	Silage based	0.9	1
1	1004	E	Silage based	0.9	1
2	1005	E	Silage based	0.9	0.95
2	1006	E	Silage based	0.9	1.1
2	1007	B	Silage based	0.9	1
3	1010	E	Silage based	0.9	1.1
4	1011	E	Silage based	0.8	1.05
4	1012	E	Silage based	0.8	1
5	1015	E	Silage based	0.9	0.95
6	1017	E	Silage based	0.9	1.2
6	1018	E	Silage based	0.9	1.08
8	1025	E	Silage based	0.9	0.9
8	1026	E	Silage based	0.8	0.97
13	1049	E	Silage based	0.9	1
14	1051	E	Silage based	0.9	1.1
14	1054	E	Silage based	0.8	1.2
15	1055	E	Silage based	0.9	0.9
15	1056	E	Silage based	0.9	1.1
15	1057	E	Silage based	0.9	1
16	1063	E	Silage based	0.8	1.05
16	1064	E	Silage based	0.8	1.05

Table 2. Animal carcass weights and grading scores achieved for the experimental animal groups

Farm Protocol	Trials (N°)	Farms (N°)	Animals (N°)	Av. Carcass Weight (Kg)	Weight Range (Kg)	Conformation Score*	Fat Score*
Enhanced							
Plant 1	8	14†	64	340.4	264.2 - 425.2	89.5	105.6
Plant 2	8	16	32	351.1	270.4 - 412.0	90.6	91.9
Basal							
Plant1	8	14†	64	333.6	263.4 - 412.0	82.9	81.5
Plant2	8	16	32	346.1	266.0 - 415.6	82.2	87.2

* Grades converted to numerical values as in Table 2b and 2c below
†Sample number from 2 farms doubled.

Table 2b. MLC Fat Class scale for beef grading

Fat Class	Numeric Value
1	20
2	45
3	65
4L	90
4H	105
5L	125
5H	145

Table 2c. MLC Conformation scale for beef grading

Conformation Score	Numeric Value
E	155
U+	140
U-	115
R	85
O+	55
O-	30
P+	20
P+	15
P-	10

Table 3. Missing data and deviations from protocols with comments

Weather data	Weather data missing for first kill at one abattoir	Weather was not extreme that day
Dam breed	2% of dam breed data from enhanced farms was missing (4ex192). For this missing data (at 1 enhanced farm) the dams were considered by the farmer/supervisors to be of at least 50 % beef breed.	Dam breed is needed to confirm enhanced cattle are at least 75% beef. Finishers with bought-in stores did not know dam breed but cattle on enhanced farms were also visually assessed (SFQC staff) as at least 75 % beef.
Carcass weight	6 samples (3 Enhanced farms) were slightly overweight (+400 kg carcass)	Over target weight but not over fat.
Farms duplicated	Cattle were sourced from two enhanced and two basal farms twice to make up numbers when scheduled deliveries were 'no show'.	Possible reduction in variability by duplicating farms
100 day pre-slaughter visit	For the first kill the initial visit was less than 100 day pre-slaughter target	It was confirmed cattle had been on finishing diets for 100 days and target gains were being achieved.

APPENDIX III: INSTRUCTIONS FOR RANDOM INDUSTRY PLANT SAMPLING

Protocol for collection of random industry basal meat sample.

1. Arrange a suitable boning day within the first week of the month allocated (unless otherwise stated) when samples can be collected.
2. At the end of the day when the selected animals have been killed, look up random numbers from first sheet in column below the number approximating to number of beef killed that day: e.g. 223 animals killed, look in column under 220
3. First kill number – 1 + first random number from sheet = kill number of first animal to be sampled, continue with next random number until you have 4 or 8 kill numbers depending upon number of samples required from that particular plant. E.g. First kill number of day =1000234 and first random number in list is 54, then 1000234 – 1 =1000233 + 54 = 1000287. Calculate a few extra in case there is something seriously wrong with one of the carcasses you have selected e.g. it was condemned. Do not use a column of random numbers more than once. I will send more if required.
4. Six inches of loin to be cut from the front end of the loin assuming that the animal was quartered at the 10th rib. Some plants quarter at the 6/7th rib and take a rib joint, which still leaves the sirloin cut at the 10th rib. It is important that samples are always taken from the front end of the loin as eating quality can vary along its length and we need to be consistent.
5. Samples to be individually vacuum packed and a laminated, University of Bristol number card (supplied) placed with each sample. It would help if a kill number could be written on this card. (marker pen supplied, allow ink to dry before putting label in bag). Please place label on fat side of sample number facing outwards. Samples should be vacuum packed and sent to Bristol to arrive within kill + 5 days.
6. It would be helpful of you were willing to supply the following data on each animal: carcass weight, MLC grade, breed, sex and main component of diet (forage, concentrates, potatoes). A data sheet is attached. You can post or fax the data sheet at your convenience.

If in doubt feel free to contact Ian Richardson on: 0117 928 9291 (sec: 0117 928 9227). Fax 0117 928 9324. e-mail Ian.Richardson@bristol.ac.uk

<u>Plants involved and numbered labels allocated</u>

	Plant	Month sampling	Allocated sample numbers		Number of samples
17	Z	Early May	257	260	4
18	Z	Late May	261	268	8
19	Z	Mid June	269	276	8
20	Z	July	277	284	8
21	Z	Sept	285	288	4
22	X	Early May	289	292	4
23	X	Sept	293	300	8
24	X	Nov	301	308	8
25	Y	Early May	309	316	8
26	Y	July	317	324	8
27	Y	Nov	325	328	4
28	W	Early May	329	332	4
29	W	Sept	333	340	8
30	W	Nov	341	348	8
31	V	Late May	349	356	8
32	V	Mid June	357	360	4
33	V	July	361	364	4
34	U	Mid June	365	372	8
35	U	July	373	376	4
36	S	Late May	377	380	4
37	T	Nov	381	384	4

Meat will be sent to Bristol immediately after cutting and matured at Bristol.

Abattoir ………………… Date of kill ………..……... Date boned ………………..……………….

Random number	Kill Number	Univ of Bristol No.	Breed	Sex	Carcass weight	MLC Fatness	MLC conformation	Diet

Collector………………………

APPENDIX IV: CONSUMER PANEL QUESTIONNAIRE

HOUSEHOLD No.

1. What is the total number of persons in your household?

2. Please, indicate these characteristics for each person in your household:

	NAME	AGE	GENDER	EDUCATION		
				School to 16	School to 18	University degree
Person 1						
Person 2						
Person 3						
Person 4						
Person 5						
Person 6						

3. Which cooking method do you normally use for (up to two choices per species):

	Pork	Beef	Lamb
Barbecue	☐	☐	☐
Fry	☐	☐	☐
Grill	☐	☐	☐
Roast	☐	☐	☐
Stew	☐	☐	☐
Other (specify):			

HOUSEHOLD No. **NAME**

4. How often do you eat the following meats at home (*please, mark the most appropriate alternative for each meat, do not include processed meats, e.g., sausages, bacon*)

	Never	< once a month	Once a month	2-3 times a month	Weekly
Pork	☐	☐	☐	☐	☐
Beef	☐	☐	☐	☐	☐
Chicken	☐	☐	☐	☐	☐
Lamb	☐	☐	☐	☐	☐
Fish	☐	☐	☐	☐	☐

5. How important for you are the following factors in terms of the satisfaction you expect from beef steaks? Assign 0 (*low importance*) to 10 (*high importance*) to each factor and your personal preference for each characteristic. Please, do not discuss your opinions with other members of your family and do not let them influence your view.

Characteristics	**Points (0 to 10)**	**Prefer**
E.g. Type of cheese	*7*	*Mature Cheddar*
Amount of liquid in the package		
Amount of liquid released while cooking		
Amount of surrounding fat		
Amount of visible fat		
Beef flavour intensity		
Brand		
Butcher		
Colour		
Doneness		
Juiciness		
Packaging		
Price		
Safety		
Store		
Tenderness		
Welfare		

HOUSEHOLD No. **SAMPLE**

If you are the cook, what do you think about the following characteristics? Tick on the line.

SIZE OF STEAK

Very small *Very big*

COLOUR OF LEAN

Very light *Very dark*

COLOUR OF FAT

Very white *Very yellow*

VISIBLE SURROUNDING FAT

Very small amount *Very large*

AMOUNT OF VISIBLE SURROUNDING FAT

Very unacceptable *Very acceptable*

VISIBLE INTRA-MUSCULAR FAT

Very small amount *Very large amount*

AMOUNT OF VISIBLE INTRA-MUSCULAR FAT

Very unacceptable *Very acceptable*

LIQUID RELEASED IN PACKAGING

None *Very large amount*

LIQUID RELEASED WHILST COOKING

Very small *Very large amount*

SIZE OF STEAK AFTER COOKING

Very unacceptable *Very acceptable*

DATE
TIME

HOUSEHOLD no

SAMPLE no

NAME

For each one of the four attributes below, mark the alternative that best represents your opinion on the sample that you have just tasted. Please, do not discuss your opinions with other members of your family and do not let them influence your score.

	TENDERNESS	**JUICINESS**	**FLAVOUR**	**OVERALL ACCEPTABILITY**
Like extremely	☐	☐	☐	☐
Like very much	☐	☐	☐	☐
Like moderately	☐	☐	☐	☐
Like slightly	☐	☐	☐	☐
Dislike slightly	☐	☐	☐	☐
Dislike moderately	☐	☐	☐	☐
Dislike very much	☐	☐	☐	☐
Dislike extremely	☐	☐	☐	☐

OBSERVATIONS: