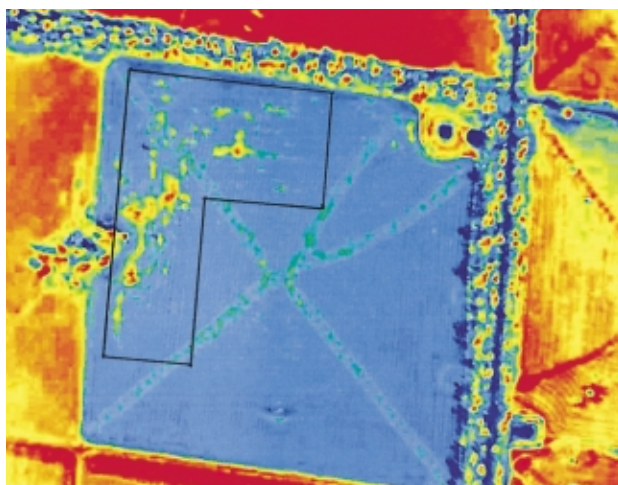


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Methods used in the CRC program for the determination of carcass yield and beef quality

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Abstract. This paper describes the methodology used for the collection of carcass yield and meat quality data from straightbred and crossbred cattle in the Cooperative Research Centre for Cattle and Beef Quality core program.

Introduction

In order to fulfil the aims of the Cooperative Research Centre for Cattle and Beef Quality (CRC), about 10 000 cattle needed to be slaughtered, processed, sampled and measured for a range of carcass and meat quality traits. Both pre- and post-slaughter treatments were standardised, to minimise confounding of genetic comparisons and management effects by variation in environmental factors. They were also designed to result in minimal animal stress and to avoid adverse post-slaughter processing effects on meat quality. Animals were slaughtered at commercial abattoirs. Due to the geographical spread and time span of CRC activities, several abattoirs were used.

In this paper, details of the methodologies used in assessing, or measuring, the carcass and meat quality traits are described. Where specific deviations from these methods occurred, they will be detailed in papers using that data.

Pre-slaughter

On farm or feedlot

The final live animal measurements were taken 1 week before slaughter to enable animals to recover from any stress associated with restraining the animals in the crush during measurement. Animals were weighed in the early morning, with no time off feed. Upton *et al.* (2001) have described the measurements taken on live animals.

Transport and lairage

The majority of cattle were slaughtered within 30 h of leaving the finishing property, the maximum being 48 h. The distance between finishing property and abattoir varied from 70 to 900 km. Cattle had access to water on arrival at the abattoir.

The CRC pre-slaughter protocol required that: (i) trucks had no protruding objects that could cause bruising or hide damage, (ii) lairage yards were as clean and as quiet as practicable, (iii) clean drinking water was available, (iv) groups were kept separate, not mixed with unfamiliar

animals, (v) dogs were not used, and (vi) use of electric prodders was kept to a minimum.

Post-slaughter

Slaughter

Animals were stunned using a captive bolt pistol and bled immediately. No electric immobilisers were used post-stunning.

Electrical stimulation

To prevent 'cold shortening' all carcasses were electrically stimulated. Most were stimulated for 40 s within 5 min of stunning, using conventional low voltage stimulation systems. The stimulation systems were configured using either a nostril clamp and rectal probe, or a nostril clamp and rubbing rail (at hip height). The peak, square-wave, voltage (45 V) was delivered as continuous pulses of alternating polarity 40 ms in duration, in a series of 3 s on and 1 s off current flows (Powell *et al.* 1983). If the stimulation procedure failed (i.e. there was no visual sign of muscle tetany) this was noted, and recorded on the CRC database.

Several abattoirs used high voltage stimulation, which was applied to the dressed sides 40–60 min post-stunning, via 2 rubbing rails. The 400–800 V (voltage differed among abattoirs) was delivered at 14.3 pulses/s, in bidirectional half-sinusoidal pulses of 10 ms width.

The carcasses received additional electrical input (generally 45–110 V applied for about 12–20 s) through a low voltage rigidity probe used during mechanical hide pulling.

Dressing procedure

Order of kill was recorded in all abattoirs by CRC personnel and related to the body number assigned by the abattoir. The left side of each carcass was used for sample collection and for measurement of carcass yield. Carcasses were dressed according to AUS-MEAT standard specifications (AUS-MEAT 1998); with the exception that

subcutaneous fat over the topside and brisket was not trimmed. The removal of any bruise and/or contaminated tissue from the left side was noted. The abattoir recorded hot carcass weight and P8 fat depth [located at the intersection of a line parallel to the spine from the tuber ischium and a line perpendicular to it from the spinous process of the third sacral vertebra, (Moon 1980)].

All carcasses were placed in chillers within 1 h of stunning, the sides being hung from the Achilles tendon. Left sides from all carcasses in each slaughter were placed into 1 chiller to minimise variation in post-slaughter chilling.

Chiller measurements

The left side of each carcass was quartered between 20 and 24 h after slaughter. Up to mid 1998 carcasses were quartered at the 12th/13th rib. Subsequently they were quartered at the 10th/11th rib.

CRC personnel made the following measurements: fat depths (P8 and 12th/13th rib, AUS-MEAT 1998); muscle score (15 point scale, McKiernan 1990); eye muscle area for sides quartered at the 12th/13th rib (measured manually from acetate tracings or from a video image of the cut surface); and eye muscle length and depth for sides quartered at the 10th/11th rib.

Qualified AUS-MEAT assessors made the following assessments, using AUS-MEAT standard reference chips (AUS-MEAT 1996): muscle colour, fat colour, marbling score (AUS-MEAT marbling score changed from a 1–12 score scale to a 0–6 score scale in 1996).

Since June 1998 Meat Standards Australia (MSA) graders have made the following additional measurements: USDA ossification score (Romans *et al.* 1994); MSA1 marbling score (new AUS-MEAT marbling score of 0–6, with decimal divisions within each score); USDA marbling score (Romans *et al.* 1994); and pH (measured in the *M. longissimus thoracis et lumborum* at about 20 h post-stunning).

Sample removal

After quartering, the entire *M. semitendinosus* (ST) and about 15 cm of the *M. longissimus thoracis et lumborum* (LT) caudal to the quartering site were removed from each left side for objective measurement of meat quality. These samples were trimmed (as specified later for yield measurement) and weighed before packaging in plastic and freezing at -20°C within 36 h of slaughter. For about 4000 carcasses slaughtered between 1997 and 2000, an additional sample of the LT was taken for sensory evaluation of eating quality. For carcasses quartered at the 12th/13th rib, the whole LT caudal to the quartering site was collected from the right hand side. For carcasses quartered at the 10th/11th rib, a sample from the left LT was collected caudal to that portion taken for objective measurements.

The LT, which is a low connective tissue muscle that is free to shorten, is the muscle most often used for meat quality

evaluation. The ST is a muscle that has a high connective tissue content and is restrained from shortening postmortem by its skeletal attachments (Shorthose 1996). It thus better reflects the connective tissue contribution to tenderness and is not affected by the cooling rate of the carcass.

Yield measurement

Initially, the carcass was broken down to 17 boneless primal cuts (AUS-MEAT 1998) by abattoir personnel and the untrimmed weights recorded. These (with their AUS-MEAT product identification numbers) were: ribset (2220), chuck (2260), chuck tender (2310), blade (2300), point end brisket (2330), navel end brisket (2340), intercostals (2430), shin (2360), topside (2000), outside flat (2050), thick flank (2060), rump (2090), striploin (2140), tenderloin (2150), thin flank (2200), eye round (2040) and shank (2360). When trimmed to commercial specifications with 10 mm fat cover the ribset produced the cube roll (2240) and the chuck produced the chuck roll (2275). When trimmed to 3 mm fat cover the thick flank (2060) became the knuckle (2070) and the rump (2090) became D-rump (2100).

These primals were prepared to commercial specifications, with the trimmings separated into intermuscular and subcutaneous fat, and manufacturing meat trim. The trimmed primal and each of the trim components were weighed separately. Subcutaneous fat was trimmed to 10 mm thickness (if fat depth exceeded this) and then for 7 cuts (topside, outside flat, thick flank, rump, striploin, eye round and blade) it was further trimmed to 3 mm. All components were weighed separately at each level of trim. All other lean tissue was classified as manufacturing meat trim and packed to an 85% chemical lean specification. Final weights for the LT and its trimmings were the sum of those for the sample LT and for that portion of the LT retained on the hindquarter. Bones were cleaned of adhering meat and fat tissue, which was weighed as either intermuscular fat or meat trim. All bones were weighed. Electronic scales, which weighed in 5 g increments, were used.

Meat trim, navel and point end briskets, chuck roll, intercostals, thin flank and shanks were boxed as manufacturing meat, sampled using a template and coring drill and fat content determined using the rapid microwave method (Anon. 1983). Weight of manufacturing meat trim (not including weight of primals included in boxed manufacturing meat) and total fat trim was adjusted mathematically by the deviation in chemical lean content from the specified 85%.

Saleable beef yield was calculated as the total weight of boneless cuts, trimmed to 10 mm fat cover, plus the weight of 85% lean manufacturing meat, expressed as a percentage of recovered side weight. Retail beef yield was calculated in a similar manner, using weights trimmed to 3 mm fat cover for those cuts trimmed to this level, plus weights trimmed to 10 mm for the remainder.

The procedures described above applied to all animals slaughtered to July 1997. Abattoir conditions precluded full yield determination on all animals after this. From mid 1997 to early 1998 straightbred animals did not have yield measured, and crossbred animals had yield at 3 mm fat cover only, measured. From the second slaughter in 1998 a modified protocol was used. This involved weighing only 9 individual primals trimmed to 10 mm subcutaneous fat. For these carcasses it was not possible to gather weight data for untrimmed primals, fat trim, meat trim or bone. The primal cuts individually weighed were: cube roll (2240), blade (2300), topside (2000), outside flat (2050), rump (2090), striploin (2140), tenderloin (2150), eye round (2040), and knuckle (2070). Saleable beef yield was estimated from the weights of these 9 cuts as described by Reverter *et al.* (1999), who showed that this provided an accurate estimation of yield.

Objective measurement of meat quality

The ST and LT samples were stored at -20°C until required. They were thawed at 4°C for 48 h before preparation for analysis. Because of the large numbers of samples to be processed and measured, 2 laboratories were used. These used standardised equipment and protocols except where otherwise described.

Initial sample preparation

The subcutaneous and intermuscular fat, and epimysial connective tissue were removed. About 50 g of subcutaneous fat trimmed from the LT was collected from about 1700 carcasses and stored at -20°C for subsequent analysis of fatty acid composition, the methodology of which is described by Smith *et al.* (1998).

A subsample 15 mm thick (about 100 g) was removed from the full length of the lateral surface of the LT sample for chemical analysis of intramuscular fat. An adjacent slice, about 4 mm thick, was removed from the fresh surface left by the removal of the intramuscular fat sample, stored at -20°C , and used for subsequent measurement of sarcomere length.

A 245–255 g sample, about $90 \times 60 \times 50$ mm, from each muscle was prepared for cooking, ensuring that orientation (cranial/dorsal/medial) was identifiable. For carcasses quartered at the 12th/13th rib, subsamples for cooking were taken from the cranial end of the sample LT, whilst for carcasses quartered at the 10th/11th rib they were taken from the caudal end of the sample. These samples were also used for meat colour and pH measurement. The cooking sample from the ST (weight and dimensions as for LT) was taken from the distal third of the muscle. A similar section from the centre of the ST was used for colour and pH measurements. These subsamples were returned to the chiller ($1-4^{\circ}\text{C}$) for a minimum of 60 min to enable the meat to ‘bloom’ (development of oxymyoglobin on the exposed surface).

Meat colour and pH measurement

Three colour measurements per sample were taken on the bloomed surface using a Minolta Chroma Meter, and then averaged. Measurements were recorded in $L^* a^* b^*$ colour space—defined by the Commission Internationale de l’Eclairage in 1976 (Anon. 1998).

Measurements of pH (ultimate pH) were taken using a digital pH meter with a combination electrode (glass body with a spear tip). One temperature and 4 pH readings were taken for each sample, with the latter averaged.

Cooking procedure

The cooking samples were weighed (pre-cook weights), placed into individual plastic bags, and held at 4°C for at least 30 min, to standardise pre-cooking temperature. The samples were placed in an 80 L water bath (preheated to 70°C) for 60 min, using a rack to ensure that samples were not touching and a pump to circulate the water so that cooking would be even. The cooked samples, still on the rack, were then cooled in cold running tap water for 30 min. Each sample was then removed from its bag, dried, weighed (post-cook weight), returned to its bag, and stored at 1°C overnight. Cooking loss was calculated as the percentage difference between pre- and post-cooked weight. A cooking temperature of 70°C was used to achieve a medium degree of ‘doneness’.

Texture measurements

After overnight storage at 1°C , the cooked samples were cut into subsamples for textural analysis. Details of sample thickness, shape and fibre orientation for samples used for shear force and compression measurements are given in Bouton *et al.* (1971) and Bouton and Harris (1972). All textural measurements were made on a Lloyd Instruments LRX Materials Testing Machine fitted with a 500N load cell (Lloyd Instruments Ltd, Hampshire UK).

Briefly, 6 subsamples with a rectangular cross section of 15 mm wide by 6.66 mm deep (1 cm^2) were cut from each block, with fibre orientation parallel to the long axis, and at right angles to the shearing surface. The force required to shear through the clamped subsample with a triangulated 0.64 mm thick blade pulled upward at a speed of 100 mm/min at right angles to fibre direction was measured as kg peak force (greatest force measured on the force-deformation curve). The mean for the 6 subsamples was recorded.

Two wedges were cut from the remaining sample so that the muscle fibre direction was parallel to the largest cut surface, and the thickness at the centre of the wedge was about 10 mm. The wedge shaped sample was placed on the testing plate so that the muscle fibres were parallel to the plate and the surface of the sample just touched the bottom of a blunt cylindrical metal rod (diameter 6.3 mm) that was positioned 10 mm above the plate. This rod was then driven

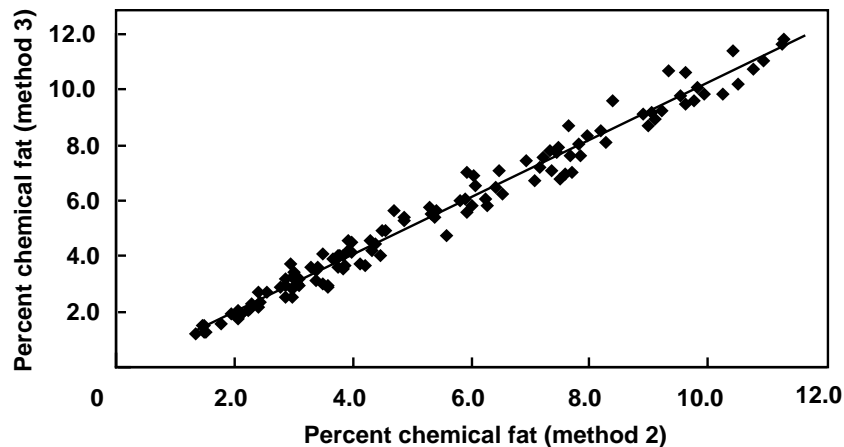


Figure 1. The relationship between percent chemical fat measured by solvent extraction (method 2) and estimated by near infrared spectrophotometry (NIR, method 3). Data from samples analysed using both methods (◆) are shown with line of best fit.

8 mm into the sample at a speed of 50 mm/min, twice at exactly the same position. The wedge was then moved and another reading taken. Six measurements were made per sample, with mean compression recorded in kilograms. Compression was calculated as the product of hardness and cohesiveness, where hardness is the maximum height of the first force-deformation curve, and cohesiveness is the work done by the second compression stroke (area under the second force-deformation curve), divided by the work done by the first compression stroke (area under the first force-deformation curve).

Intramuscular fat percentage

Intramuscular chemical fat percentage was determined only for the LT sample. The samples were homogenised (ground) for several seconds using a domestic blender. Three procedures were then used, 2 of which were based on solvent extraction using a Soxhlet apparatus, and the third used near infrared spectrophotometry (NIR) to estimate chemical fat content. Samples were analysed in 2 laboratories using different methods according to availability of equipment and to safety regulations. Inter-laboratory comparison of methods, using common samples, showed no consistent bias in the measurements using the different methods. All data base records for intramuscular fat percentage include the method used.

Method 1. About 10–20 g of homogenised sample was packaged in filter paper, oven dried at 102°C for 18 h, with percent moisture content calculated from pre-and post drying weights. The dried samples were then placed in a multi-sample Soxhlet chamber for 48 h (about 48 fluxes), with petroleum ether used as the solvent. Samples were oven dried at 80–102°C for at least 2 h before weighing.

Method 2. About 100 g of homogenised sample was frozen at –20°C until ready for freeze-drying. After

freeze-drying, samples were placed in a 50°C oven for at least 24 h before weighing for calculation of moisture content. Freeze-dried samples were finely ground (using a domestic blender).

Weighed samples (about 6 g) were packaged in filter paper and placed in a multi-sample Soxhlet chamber for 48 h (about 24 fluxes). Due to safety regulations, chloroform rather than petroleum ether was used as the extracting solvent.

Samples were dried for at least 72 h before weighing, at 50°C to November 1997 and at 80°C after this date, to ensure all chloroform was evaporated from the sample.

Intramuscular fat percentage was calculated as the proportional difference between the weight of the dried sample before (W1) and after (W2) solvent extraction, multiplied by percent dry matter (DM) of the original ground sample ($(W1 - W2 / W1) \times DM\%$), and recorded as a percentage of wet sample weight.

Method 3. Samples were freeze-dried, weighed and finely ground as for method 2. Ground dried samples were then analysed in a Technicon Infralyser 450.

Estimation of percentage chemical fat. Development of an equation for the estimation of percentage chemical fat by NIR used data from 323 samples that had both solvent extraction data (method 2) and NIR readings. A principal component analysis gave coefficients for each of the 19 wavelengths in relation to percentage fat as measured by solvent extraction. After calibration and validation, 10% of all samples analysed by method 3 were routinely monitored using method 2. This indicated that the NIR equation was overestimating chemical fat for samples with greater than 12% chemical fat as measured by method 2 (the maximum chemical fat in the calibration set was 10%). Therefore all samples that were estimated as having more than 12% chemical fat (method 3) were processed using method 2.

Figure 1 shows the relationship between percent chemical fat as estimated using NIR (method 3), and as measured using solvent extraction (method 2).

Sarcomere length

Sarcomere length was measured using a Helium-Neon laser diffraction technique on unfixed frozen (-20°C) muscle. The laser had a wavelength of 635 nm, and was used as the light source to obtain diffraction patterns from muscle fibre samples held between glass microscope slides. Sarcomere length was determined from the diffraction pattern displayed on a frosted screen (Bouton *et al.* 1973). Sarcomere length (μm) was calculated from the average distance (mm) of the inner and outer diffraction bands from the centre of the screen. The mean of 5 readings was taken per sample.

Sensory evaluation of eating quality

Consumer assessment of the palatability of LT samples was done by MSA. A detailed description of the preparation, cooking, and tasting protocols is available in Polkinghorne *et al.* (1999). Briefly, LT samples taken for sensory analysis were aged at 1°C for 14 days, the epimysium removed and 6 steaks (25 mm thick) prepared from each sample. These were stored at -20°C until required. All steaks were cut from that portion of the LT immediately caudal to the 12th/13th rib, regardless of quartering site. Untrained consumers did the assessment, with each steak halved and assessed by 2 consumers. Assignment of steak halves to taster, tasting session and order of presentation was done using a latin square design. All steaks were served grilled, to a medium degree of 'doneness' (70°C internal temperature), using standardised cooking equipment, grill temperature and cooking time. Steaks were assessed for tenderness, juiciness, flavour and overall acceptability using 4 unstructured 100 mm lines anchored by the words very tough/very tender for tenderness, very dry/very juicy for juiciness and extremely dislike/extremely like for both flavour and overall acceptability. These 4 sensory dimensions were combined into a single palatability score (MQ4) using weightings formulated from a discriminant analysis. The weightings were 0.4, 0.1, 0.2 and 0.3 for tenderness, juiciness, flavour and overall acceptability, respectively (Polkinghorne *et al.* 1999).

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