Guaranteed eating quality: the Australian science

JM Thompson[1], D Perry[2], AF Egan[1], WR Shorthose[3]

Cooperative Research Centre for Beef Genetic Technologies
[1]School of Rural Science, University of New England, Armidale, NSW, 2351
[2]NSW Dept of Primary Industries, University of New England, Armidale, NSW, 2351
[3]Food Science Australia, Tingalpa DC, Qld, 4173

Abstract

This paper reviews the outcomes of a series of research programs undertaken by the Beef CRC and MSA to understand the impact and mechanisms by which critical control points during the production, processing, lairage and processing phases impact on beef palatability. Production factors which impact on palatability include Bos indicus content, growth rate and HGP implantation. All these appear to operate to some degree on the rate of protein degradation in the live animal which results in lower palatability post-mortem. Stress effects during lairage influence the mobilization of glycogen which will impact on ultimate pH and can produce darker meat which is varyingly palatable. During processing the management of electrical inputs is critical to achieving an optimal pH and temperature decline. Mismanagement during this process will result in cold or heat shortening will impact negatively on palatability. Tenderstretch provides insurance against the extremes in processing by physically either stopping the myofibres from contracting excessively or by stretching them. Under optimal processing conditions there is minimal difference between similar muscles of tendertstretch and Achilles hung carcasses.

The partnership between Beef CRC and Meat Standards Australia (MSA) has provided a conduit for the rapid implementation of research results. The end result of this research has been the MSA model that has provided the Australian consumer with a guarantee of eating quality.

Key words: consumer sensory scores, palatability, Bos indicus effect, growth rate, Hormonal growth promotants (HGPs), stress, saleyards, pH/ temperature window, tenderstretch, marbling.

Introduction

The first Beef Co-operative Research Centre (CRC), commenced in 1992, was focused on research to better meet market specifications. As part of its research portfolio the Beef CRC set up a number of long-term genetic, nutritional, management and meat science programs which were aimed at providing the tools for the Australian beef industry to achieve better compliance with market specifications.

In parallel, the Meat Research Corporation embarked upon the development of a national meat grading scheme which was focused on accurately describing eating quality for the consumer. During the later part of 1996 and early 1997, discussions were held with interested parties, including the Beef CRC, to formulate a proposed structure for the new meat grading scheme. The intention was to develop a total systems approach, whereby the critical control points that impacted on palatability were identified and incorporated into a grading scheme, focused on delivering palatability to the consumer. The grading scheme, which was initially known as the Eating Quality Standards program, was later renamed Meat Standards Australia (MSA).

The focus on eating quality set the stage for a large collaborative research effort between the Beef CRC, other research providers and the MSA program. In particular the MSA consumer testing protocol provided a common means of evaluating the meat quality endpoints for a large number of experiments. These research projects aimed to quantify the magnitude of various effects on meat quality and to understand the mechanisms by which these critical control points impacted on beef palatability. The outcomes of this research underpinned the development of the MSA beef grading prediction model. This paper will review some of these meat science contributions arising from the partnership between the Beef CRC and MSA and how these results have been used to guarantee eating quality for the Australian consumer.

Production factors

Breed

Breed differences in beef palatability have centred around the Bos indicus content of the animal. The importance and magnitude of the Bos indicus effect on palatability has been recently reviewed

by Burrow et al. (2001). The Bos indicus effect is particularly relevant to Australian beef production systems, where Bos indicus derived cattle comprise almost 40% of the Australian cattle herd (Bindon & Jones 2001).

An early Beef CRC study by Rymill (1997) showed that a Bos indicus effect was evident, whereby at levels of greater than 75% Bos indicus, there was a marked decline in palatability under a number of different processing scenarios. Other studies which reported the magnitude of the Bos indicus effect tended to vary in the level of Bos indicus content at which a decline in palatability occurred, with some experiments showing that greater than 25% Bos indicus content had an impact on palatability (e.g. Morgan et al., 1991), whilst others concluded that 50% (Sherbeck et al. 1995), or even 75% (Rymill, 1997) Bos indicus content was required before consumers could detect a decline in palatability. Using samples from the same experiment as Rymill (1997), Ferguson et al. (2000) reported that increased Bos indicus content resulted in increased calpastatin activity which was consistent with the increased shear force and toughness. Interestingly, they reported an interaction between Bos indicus content and electrical stimulation for calpain activity (both μ-calpain and m-calpain) suggesting that stimulation reduced the breed effect. This interaction was significant for shear force (but not for sensory tenderness score) and showed a reduced Bos indicus effect in stimulated sides compared with non-stimulated sides.

As MSA moved towards the cuts-based-grading system there was a large research effort to quantify the impact of Bos indicus content on individual muscles in the carcass. Earlier work by Shackelford et al. (1995) examined the effect of the interaction between Bos indicus content and muscle on palatability. They showed that the Bos indicus effect was significant for theMm. triceps brachii, longissimus dorsi, supraspinatus, biceps femoris and quadriceps femoris and not for a number of other muscles that were tested. The Beef CRC and MSA initially examined the interaction between Bos indicus content and muscle palatability using muscles from 50 milk-fed vealers and 40 heavy pasture-fed steers, which ranged in Bos indicus content from 0 to 100% (Thompson et al. 1999a). At slaughter, carcasses were stimulated using a low voltage system and one side was tenderstretched. The results showed a Bos indicus content x muscle interaction, with a decline in palatability with increased % Bos indicus content most evident for the muscles surrounding the spinal column (i.e. Mm. longissimus and psoas). These muscles showed nearly a 10 point decrease in palatability over the range of 0–100% Bos indicus content. These results indicated that it was not appropriate to have a single Bos indicus adjustment across all muscles, as the magnitude of the Bos indicus effect was muscle dependent. Since this early experiment the quantification of the Bos indicus effect has been expanded to test more muscles using a wider range of cooking techniques. In the MSA system the Bos indicus content was therefore an important CCP.

Growth path

Rapid growth over the lifetime of the animal is often cited by industry as resulting in more tender and palatable beef. However when the literature on the effects of growth path on beef palatability were examined the results were variable. Fishell et al. (1985) reported that steaks from the m. longissimus of faster growing groups of cattle were more tender than those from than slower growing groups, although others (Calkins et al. 1987; Moloney et al. 2000) found no relationship between daily gain and shear force or tenderness scores in the m. longissimus fast and slow growing groups. In contrast, Shackelford et al (1994) reported that within a group, there were negative correlations (both genetic and phenotypic) between average daily gain and shear force of the m. longissimus. In other words, within a group the faster growing animals had a lower shear force (and were more tender) than slower growing animals.

Perry and Thompson (2005) proposed a model to explain this inconsistency between studies. They proposed that variation in the growth rate of animals can arise in a number of ways. Firstly, growth rate of a group can be manipulated by altering the amount or quality of feed available for growth. In this case, differences in average growth rate between groups of animals would reflect variation in a combination of nutritional, management and environmental factors. Secondly, within a group the growth rate of an individual animal, whether under ad libitum or restricted feed conditions, will tend to reflect its genetic potential for growth (i.e. larger mature size animals will grow faster at any age than small mature size animals, Thompson and Barlow 1985).

Perry and Thompson (2005) used the results of a large Beef CRC study to demonstrate that the mechanism for increased gain may not be the same in these two scenarios. In their study, data on the growth path of 3,370 temperate cattle and 3,523 tropically adapted cattle had been monitored for growth from weaning to slaughter. After arriving at the backgrounding properties animals were allocated to either grain or grass finishing systems, which were slaughtered at either domestic (220 kg carcass weight), Korean (280 kg carcass weight), or Japanese (340 kg carcass weight) weights.

In total there were 79 and 93 slaughter groups for the temperate and tropically adapted animals, respectively. These different groups were slaughtered at 5 abattoirs over a 4 year period. At slaughter the m. semitendosus and the anterior

portion of the m. longissimus were collected from all carcasses and aged 1 day for objective measurements, whilst from a sub-set of carcasses the adjoining portion of the m. longissimus was also removed and aged for 14 days, prior to consumer testing using the MSA tasting protocol. The analyses assessed the importance of growth rate during backgrounding and finishing on both a within and between group basis in the temperate and the tropically adapted animals.

Although there were some inconsistencies in the magnitude of the response, the significant results showed that for individual animals within a group, increased growth rate resulted in a higher palatability. The relationship was more significant for growth rate during the finishing period than for the backgrounding period. Similar relationships between growth rate and shear force were evident in the m. longissimus (a low connective tissue muscle which could shorten under poor processing) and the m. semitendinosus (a high connective muscle under tension during the onset of rigor and therefore relatively independent of processing).

Muscle accretion in a growing animal is a function of the rate of muscle synthesis minus the rate of muscle degradation. As discussed by Koohmaraie et al. (2002) the rate of muscle synthesis has no impact on tenderness of the meat, rather it was the rate of muscle degradation which impacted on ageing rate post-mortem and ultimately tenderness. Shackelford et al. (1994) showed that within a group, the faster growing animals had a negative genetic correlation with calpastatin, which would inhibit both protein degradation in the live animal and the rate of ageing in the carcass post-mortem. Although calpastatin activity was not measured by Perry and Thompson (2005) it then followed that the faster growing animals within groups would have a lower level of calpastatin, which was reflected in more palatable meat when samples were evaluated by objective measurements at 1 day or sensory panels at 14 days ageing. However whilst this is a plausible hypothesis there are some inconsistencies with the literature with Oddy et al. (1998) showing that selection for high yearling weight gain within Angus cattle had reduced muscle protein degradation, increased calpastatin activity and reduced rate of post-mortem tenderisation (McDonagh, 1998).

The study by Perry and Thompson (2005) found no relationship between mean growth rate of the group during backgrounding or finishing and mean meat quality, when adjusted for mean age of the group. In other words if growth rate of a group of animals was manipulated by varying either the quality or quantity of feed, this had little impact on meat quality when differences in mean slaughter age were taken into account.

As growth rate in the MSA model was calculated for each animal, rather than for groups, it was the relationship between growth rate of individual animals within a group that was of interest. Under this scenario, Perry and Thompson (2005) showed a curvilinear relationship between finishing growth rate and palatability which appeared to plateau at a growth rate of approximately.1.2 kg/day. The similarity in the shape and points of inflexion of the curvilinear relationships for both the temperate and tropical breeds would suggest that the results were transportable between breed types and across environments.

Hormonal Growth Promotants (HGPs)

HGPs are widely used in the Australian beef industry as a means of increasing productivity in both the grass and grain fed sectors (Hunter et al. 2001a). However, whilst there are clear benefits of HGPs in terms of liveweight gain and feed efficiency, there are also some negative effects with a reduction in marbling score and an increase in dark cutters (Duckett et al. 1997; Hunter et al. 2001b).

Unfortunately the literature on the impact of HGPs on tenderness is less clear. As early as 1991 questions were raised in the National Beef Quality Audit in the United States as to the potential for HGP implants to reduce beef tenderness (Smith et al. 1992). Since then a large number of studies have been undertaken, although the individual results from these studies have failed to clarify the position regarding HGPs and palatability. Many showed small negative effects which often the authors chose to interpret as not being significant and therefore not having an effect. In a recent review of the literature Nichol et al. (2002) concluded that HGPs had only a limited, if any, effect on beef palatability. In contrast, Dikeman (2003) concluded that tenderness was reduced in implanted compared with non-implanted cattle.

Reanalysis of some early results from an experiment of the Beef CRC/MSA suggested an effect of HGP implantation on the palatability of beef. With the aim of both the Beef CRC and MSA to predict beef palatability and to minimize variation in the quality of beef, the potential magnitude of a HGP effect on palatability was an important question. Several collaborative experiments between the Beef CRC and MSA were conducted to quantify the effect of HGPs on palatability for possible inclusion in the MSA prediction model. The first reported by Thompson et al. (2006) examined the impact on palatability of treating steers and heifers with Revalor -S and -H, respectively. In this experiment animals were finished in a domestic feedlot and 9 muscles/muscle portions collected and aged for 5 or 21 days before testing using the MSA consumer protocol.

The most dramatic response was that the impact of HGP implantation on tenderness and palatability scores varied with muscle. The greatest response to HGP implantation was in muscles such as the m.

longissimus which had the highest ageing rates and which showed an 8 to 9 point HGP penalty in palatability. In the mm. infraspinatus, triceps brachii or semitendinosus ,which effectively showed no improvement in palatability with ageing, the HGP penalty was less than 1 palatability unit.

The general consensus from the literature was that HGP implants resulted in an increase in muscle protein synthesis (e.g. Vernon & Buttery 1978, Johnson et al. 1996), although the relative contributions of synthesis and degradation varied between studies. Some studies have reported no effect of testosterone and estradiol on protein synthesis, or degradation rates (Roeder et al. 1986, Desler et al. 1996), whilst others showed an increase in protein synthesis alone (Martinez et al. 1984, Hayden et al. 1992). A recent study by Kerth et al. (2003) concluded that implantation of cattle with trenbolone acetate impacted on both synthesis and degradation, with perhaps the strongest effect on protein synthesis.

The interaction between HGP and muscle on palatability raised some interesting questions as to the possible mechanism. As mentioned previously Koohmarie et al. (2002) concluded that an increase in protein synthesis per se was unlikely to impact on tenderness, rather it was the degradation rate, controlled by calpastatin activity, that was important in determining tenderness. Ouali and Talmant (1990) reported that differences in calpain/calpastatin ratios in beef muscles contributed to differences in ageing rates across the musculature of the carcass. Those muscles with the faster ageing rates have lower levels of calpastatin. In a review of factors controlling meat tenderness Dransfield (1994) concluded that HGPs increased calpastatin in the live animal. This was supported by Gerken et al. (1995) who showed that implants containing both oestradiol and trenbolone acetate resulted in an increase in calpastatin activity. Presumably this increase in calpastatin occurred across the musculature and therefore those muscles with the highest calpain/calpastatin ratio (and, therefore, highest ageing rate) would show the greatest proportional change and therefore the greatest response on post-mortem tenderness. Whilst protease activities were not measured by Thompson et al. (2006) in individual muscles, aging rates were, and those muscles with the highest ageing rates also had the greatest HGP penalty on palatability. By design, this experiment used an aggressive HGP implant regime and the cattle were slaughtered within the payout period.

Another Beef CRC/MSA experiment was undertaken by McIntyre (unpublished data) to examine whether the HGP effect on palatability was confined to the recommended payout period. The experiment used groups of grass fed steers which comprised a control group (no implant) and an early implant group (given a Revalor-G implant 141 days prior to slaughter), a late implant group (given a Revalor-G implant 57 days before slaughter) and a group which received both early and late implants. Only grilled m. longissimus steaks were tested. The consumer palatability scores showed no difference between the early, late or early/late HGP treatments indicating that the effect of the HGP implant on palatability extended well beyond the recommended payout period.

Whilst there is some evidence that the combination of androgenic and estrogenic compounds give rise to increased muscle, in part by a decrease in protein degradation rates (Kerth et al. 2003), a recent review by Oksbjerg et al. (2004) also concluded that administration of estrogenic compounds alone may also achieve part of their growth response by decreased protein degradation. As discussed earlier the evidence from the breed studies suggested that in part the Bos indicus response was also operating via a similar mechanism. Using CRC/MSA data where estradiol-17β had been administered to both crossbred and purebred Bos indicus steers, Thompson et al (2006b) examined the potential interaction between these effects. They showed a significant interaction between the breed groups where 50% Bos indicus animals showed a 2 to 3 point decrease in sensory scores due to implantation with estradiol-17β, whilst this increased to to 8 to 10 points in the 100% Bos indicus group.

It is of note that the 3 critical control points arising from the production sector have all involved mechanisms which have been discussed in this paper have decreased protein degradation which has impacted adversely on palatability. Koohmarie et al. (2002) concluded that the suppression of protein degradation seemed to be the mechanism that is responsible for differences in the rates of muscle growth in domestic animals. Based on his model, if the increased muscle growth was instead achieved by increased synthesis alone, it would be unlikely to impact on tenderness, but the downside would be that the animal would not be as efficient during the growth period.

Lairage factors

Stress in a number of forms will deplete glycogen reserves. Ferguson et al. (2001) concluded that the emotional state of the animal was probably more critical in mobilizing glycogen reserves than was activity that was not physically demanding (e.g. during transport). The effect of transport on glycogen mobilization and ultimate pH post-slaughter is not well documented and tends to vary with the type of animal, nutritional status and the conditions during transport (Tarrant, 1990). The review by Ferguson et al. (2001) concluded that, given ideal conditions, transport distances of less

than 400 km were unlikely to deplete glycogen reserves sufficiently to impact on ultimate pH.

In Australia almost half of all prime cattle are marketed through saleyards. This method of selling is more popular in the southern states and also with small lots of cattle. Initially MSA required direct consignment of cattle to the abattoir in an effort to minimise stress and the subsequent depletion of glycogen reserves. Warner et al. (1998) found that the combination of low nutrition and saleyard selling depleted glycogen levels in the muscle. More recently, Ferguson et al. (2006) reported a comparison between direct consignment and best practice saleyard selling methods. The best practice saleyard option required animals to be well handled, not mixed, have water available and be slaughtered the day after dispatch from the farm. Their results showed a general trend for steaks from saleyard cattle to have marginally lower palatability scores compared to those from direct consignment cattle in 5 of the 8 groups tested. They concluded that marketing method had a small but variable impact on palatability and meat quality. Based on these results MSA has introduced a saleyard option with a 5-point palatability penalty, relative to direct consignment, for all muscles.

Glycogen reserves at slaughter are a function of the initial levels of glycogen and the losses due to stresses placed on the animal during the immediate pre-slaughter period. Feedlot cattle had higher on-farm glycogen concentrations in their muscle and lost less glycogen during the loading, transport and lairage period than pasture fed cattle (D. Pethick, unpublished data). The net result is that feedlot animals generally have a higher buffer of muscle glycogen at slaughter and, therefore, a lower incidence of dark cutting.

Feedlot practices frequently lead to a proportion of cattle in a pen being drafted for slaughter with the remainder being remixed. This was examined in a Beef CRC experiment by Colditz et al (2006). They showed that objective measurement of tenderness indicated mixing steers one week before slaughter led to higher compression and a tendency for higher peak force values than control animals, however, these assessments were not matched by changes in sensory perception of meat quality. Their study confirmed the impact of flight time on growth rate during feedlot finishing, and that mixing cattle less than two weeks before slaughter may compromise meat quality.

Techniques to either boost initial glycogen levels, or to minimise losses during transport and lairage, were discussed by Pethick et al. (1999). Short-term grain feeding prior to slaughter has been shown to have a positive response if suitable rumen modifiers are included to control acidosis (Gardner 2001). Supplementation using electrolyte preparations has had limited success in Australia, largely due to variation in intake. Other supplements such as magnesium oxide, whilst successful in sheep (Gardner et al. 2001a), have not been successful in cattle (Gardner, 2001). Whilst stress can rapidly deplete muscle glycogen reserves, repletion takes considerably longer and depends upon how severely animals were depleted and upon access to and the quality of the feed during the repletion phase (Pethick et al., 1999; Gardner et al. 2001b).

Processing factors

pH/temperature window

The pH/temperature window was one of the initial specifications for the MSA 'carcass pathways' grading scheme. The concept of the window originated from the results of Locker and Hagyard (1963) who showed that myofibrillar shortening occurred when pre-rigor muscle was held at either low or high temperatures. At low muscle temperatures extensive shortening occurred and the subsequent increased toughness was termed 'cold shortening'. Pearson and Young (1989) considered that for cold shortening to occur the muscle pH had to be greater than 6.0 with ATP still available for muscle contraction and the muscle temperature to be less than 10oC. At high muscle temperatures some shortening also occurred, in some cases (but not all) leading to increased toughness (Simmons et al. 1997; Uruh et al. 1986). This effect was termed rigor or heat shortening and was considered to be due to the combination of high temperature and low pH in the muscle causing early exhaustion of proteolytic activity (Dransfield, 1993; Simmons et al.1996), and increased drip loss (Denhertogmeischke et al. 1997).

More recently, the Beef CRC examined the effect on glycolytic rate, protease activity and subsequent meat quality of applying stimulation either immediately after slaughter, or just prior to entry into the chiller (Hwang and Thompson 2001a). This study confirmed that early application of stimulation was associated with a very rapid decline in pH, which led to exhaustion of the protease system (i.e. lower μ-calpain and higher calpastatin activities) with resultant higher peak force. In a subsequent Beef CRC study a combination of stimulation and chilling treatments were used to cause independent variation in pH and temperature decline (Hwang & Thompson, 2001b). A combination of excessive stimulation and high temperatures caused a rapid fall in pH which accelerated and ultimately exhausted the activity of the μ-calpains, leading to the reduced ageing potential in heat shortened meat. Their study also showed that the optimum pH decline to produce the most tender meat after 14 days of age was achieved with a temperature of 29–30 oC at pH 6. This was higher than estimates of the optimal rigor temperature of 15–18oC obtained

from in vitro studies (Devine et al. 1996; Locker & Hagyard, 1963). More recent work in sheep confirmed an optimal temperature at pH6 was of the order of 20oC (Thompson et al. 2005).

When the MSA pH/temperature window was implemented as part of the abattoir audit it was found that many abattoirs were effectively over-stimulating, with carcasses clearly entering the heat shortening region (i.e. achieving pH 6 at temperatures greater than 35oC). This was due in part to other electrical inputs being installed in the slaughter chain (e.g. immobilisers and rigidity probes),which, along with electrical stimulation, accelerate glycolytic rate (Petch & Gilbert, 1997). It is clear that differences between abattoirs in the positioning of the stimulator, effectiveness of contact electrodes, the electrical settings and wave characteristics along with the speed of the chain make it impossible to recommend a uniform protocol for stimulation.

MSA currently audit individual abattoirs and then adjust the electrical inputs to match the window specifications. However, despite constant monitoring by MSA, there is still variation in glycolytic rate both between and within lots of carcasses. Abattoir audits by MSA indicate that grain fed carcasses require less stimulation than grass fed carcasses to achieve a similar glycolytic rate, as do heavy compared with light carcasses. As part of a benchmark study to quantify the sources of variation in glycolytic rate Daly (2005) found that glycogen reserves at slaughter were positively related to glycolytic rate. However, within grain or grass fed carcasses the variance in temperature at pH 6 was of the order of 4.5oC. This study did not identify any production factors, such as transport distance or time, that were associated with this variation.

Current research in this area is aimed at developing better control of the electrical inputs by integrating them into a computer controlled system which can monitor and optimize for all electrical inputs in the chain. The new package includes immobilsers at a frequency which does not impact on glycoltyic rate, low voltage stimulators that enhance bleeding and provide some impact on glycolysis and midvoltage stimulators at the end of the chain which can measure the degree of stimulation required for individual carcasses and act as a top-up before placing the carcass in the chiller.

Tenderstretch

Tenderstretch, or pelvic suspension, has been used to underpin a number of carcass quality assurance schemes focused on eating quality (Ferguson et al. 1999; MLC 1991). The mechanisms by which tenderstretching pre-rigor impacts on eating quality is thought to occur via the stretching effect on both the myofibrils and connective matrix (Bouton et al., 1973; Hostetler et al., 1972). Tenderstretching increases sarcomere length, thereby reducing the overlap between actin and myosin. However, as shown by Hopkins and Thompson (2001), there was no relationship between the energy required to dissociate the actomyosin complex and tenderness in muscle samples subjected to different levels of stretching pre-rigor and, therefore, different levels of actin/myosin overlap. This suggested that mechanisms other than actin/myosin overlap were responsible for the improvement in palatability with tenderstretching, possibly associated with more rapid degradation of structural proteins at the junction of the Z disk and intermyofibre filaments.

Previously most studies have compared tenderstretched and normally hung sides in carcasses which were not stimulated. An interesting feature of the results by Ferguson et al. (1999) was that the improvement due to tenderstretch was also obtained in stimulated carcasses, suggesting that stimulation and tenderstretch were, to a degree, additive in their effects on palatability. Sorheim et al. (2001) reported that in unstimulated carcasses the magnitude of the tenderstretching effect interacted with chilling temperature. The greatest difference between tenderstretch and normally hung sides occurred when sides were rapidly chilled, presumably because the normally hung sides cold shortened. Thompson et al. (2005) reported that in sheep carcasses there was a curvilinear relationship between temperature at pH6 and palatability in normally hung carcasses, indicating a decrease in quality at both high and low rigor temperatures. Interestingly, there was no relationship between sensory tenderness scores and temperature at pH6 in tenderstretched carcasses. Importantly, if normally carcasses went through rigor at 20oC, they were similar in eating quality to tenderstretched samples. This suggested, firstly, that if normally hung and tenderstretched carcasses are processed at optimal temperatures there may be little differences in tenderness. Secondly, tenderstretch acts as an insurance against variable processing conditions, with less variation in tenderstretch samples than in normally hung carcasses.

Commercially, carcasses can be tenderstretched by suspending either through the aitch bone (obturator foramen) or through the pelvic ligament. As the suspension fulcrum is not the same for these two methods, different tension is placed on individual muscles in the leg and loin. A Beef CRC/MSA experiment (Hwang et al. 2002) examined the effect of differences in the fulcrum point on palatability and showed that, whilst both techniques placed increased tension on the major muscles of the loin and leg, there were differences in the tension placed on different muscles with some of the minor muscles showing degrees of shortening with ligament hanging. They showed that the position effect in the striploin in normally hung carcasses, whereby the anterior portion had a

higher palatability score than the posterior section, was lessened by suspending carcasses from either fulcrum point. For the larger muscles in the hindlimb there was a trend for suspension by the ligament to result in longer sarcomeres, although this was not reflected in either shear force or palatability score. When pooled across the hindquarter and loin muscles, suspension by the aitch bone resulted in an increase of ca. 3 palatability units, relative to suspension by the ligament.

Marbling

Although marbling is an integral part of most beef grading schemes the literature suggests that it has only a minor association with palatability (Dikeman 1996). The biology of marbling fat and how it can be manipulated by both management and genetic factors will be covered in other papers in this conference.

What is less well known is how marbling impacts on palatability. A Beef CRC study investigated the relationship between consumer taste panel scores and marbling measured by intramuscular fat percentage (Thompson 2004). This study showed a curvilinear relationship between intramuscular fat percentage and sensory scores indicating that for Australian consumers the relationship plateaued (the points of inflexion were estimated to be 14 and 20% intramuscular fat percentage for flavour and juiciness scores, respectively).

In a subsequent study using a much wider range in intramuscular fat and Korean consumers, Park et al. (2006) failed to find a curvilinear relationship. They measured intramuscular fat in 3 muscles of different connective tissue content collected from tenderstretch and normally hung carcasses, and it was interesting that the slopes of the relationships between intramuscular fat and sensory scores were similar between all muscles/treatment groups. The slopes showed that a 1% increase in intramuscular fat resulted in a 1 unit increase in palatability on a 1 to 100 scale. This suggests that the mechanism by which intramuscular fat operates in meat was similar in all muscle/treatment groups, possibly due to low density fat diluting higher density heat denatured protein.

Implementation of research results

The last 14 years have seen considerable Australian research funds and experimental resources committed to undertaking research on those factors that impact on beef quality. A large amount of this research has been through a partnership between the Beef CRC and MLA, whereby the critical control points which impacted on meat quality were quantified and the mechanisms sufficiently understood to develop the MSA beef grading model.

This unique grading scheme has incorporated the results of numerous research projects together into a functional model which operates and grades muscles at a commercial level within the domestic beef industry. As discussed in other papers at this conference the MSA grading scheme has provided the building blocks on which to build innovative procurement, processing and retailing schemes.

The relationship between Beef CRC researchers and MSA has provided an enviable conduit by which research has been implemented by industry with a minimal time lag.

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