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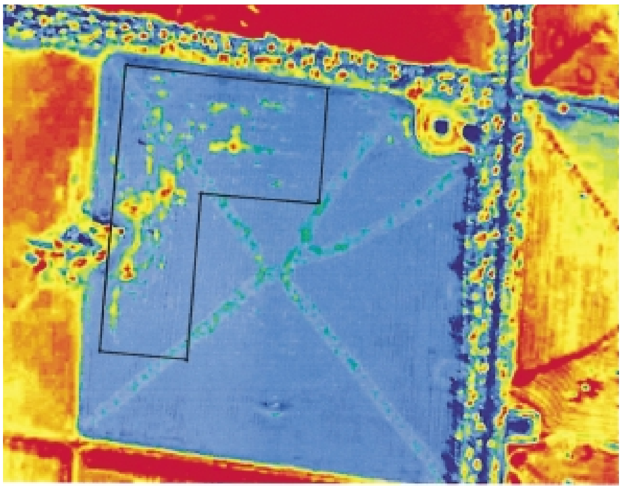

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International significance of Australian research on beef quality — a view from the periphery

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Abstract. Australia produces agricultural products, including meat, as major items for export as well as being consumed locally. It is no accident that Australia is one of the major exporters of meat to distant markets and the success is predicated on adapting animal production practices and processing to produce a highly desirable product that is safe to eat. Research plays a large part in this strategy, but one would have to say that for some time the view that '*a prophet hath no honour in his own country*' has predominated. The Cattle and Beef CRC is designed to improve the profitability of the Australian beef industry by bringing in partners, some of whom were prominent in previous research endeavours to coordinate a research effort in order to benefit the whole industry — it is a unique and effective approach. It has taken some time to demonstrate that a 'nice' looking animal is not a predictor of meat quality — rather it needs to be processed correctly in order for it to meet the most critical consumer requirements. The researchers in Australia have in fact been the world leaders in advocating procedures such as electrical stimulation that have been taken up by the industry. There are still areas where the research results from Australia differ from that in other countries. CRC-based research in Australia in controlled studies using large numbers of animals with a wide genetic base, has shown that both cattle with a significant component from tropical genotypes and non-tropical genotypes, processed correctly, produce highly acceptable meat. To get further improvements, we merely need to identify the causes of outliers and this should not be difficult. This concept is of course important in the context of the relatively dry Australian climate that results in different problems from other countries. One important outcome of the CRC has been to show that sectors of the industry need to work together to use research and, if necessary, challenge current thinking imposed from outside. In other words, Australians should believe in themselves.

Introduction

'A prophet hath no honour in his own country' (Holy Bible, John 4:44).

This review is my personal perspective of the Australian meat science scene and its contribution to the Australian meat industry. As this view is from outside Australia, it can easily be discredited, but alternatively it could be regarded as considering facts that, those who are too close to them, often do not value. It is meant to be provocative rather than conservative and the final judgement perhaps should not be made at the beginning of this century, but rather in a decade when comments will stand or fall on their merits. Good research lays a foundation for the developments of technology and this takes a longer time than the rises and falls in commercial returns. If the industry remains viable in the face of competition from other countries, then one could say that the research has been successful and the investment vindicated, as these other countries are also doing research, effectively in competition.

There has been a great deal of meat and animal science research undertaken in Australia that has underpinned the successes of the Australian animal industries and that either has gone largely unrecognised, is incompletely used, or the work from other countries has taken precedence (usually out of context). This should not happen as the Australian scientists have the same abilities as those in the rest of the world. I believe that if all the information available was used today, the meat leaving Australia would also be the best in the world, with the guarantee that this was so and Australia would be the market leader. Consumers have had no real base on which to make a purchase, but now research data can be used to put standards in place. The Meat Standards Australia (MSA) grading scheme has focused on guaranteeing eating quality to consumers by using a total systems approach through controlling factors that impact on meat quality from the production, processing and value-adding sectors of the meat production chain, rather than relying solely on carcass assessment. It would be fair to say that this concept reflects the culmination of much of the earlier research undertaken by the scientists and the Australian meat industry as well as bringing aspects gleaned from researchers elsewhere. Such a scheme is not unique and reflects the worldwide trend to provide a better quality product for the consumer such as the New Zealand Beef and Lamb Quality Mark and Blueprint for eating quality in the UK and those being developed in other countries. The MSA system is no accident — it is predicated on research.

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Clearly, there is a problem in getting information to the end user (a problem for all science endeavours); however, the Co-operative Research Centre (CRC) concept has an important part to play in developing and channelling innovations and intellectual property in a way to be taken up by the meat industry. No other country has this concept in operation the way it is done in Australia. The Cattle and Beef CRC was designed to improve the profitability of the Australian beef industry by bringing in partners, some of whom were prominent in previous research endeavours. The joint venture was between the University of New England, CSIRO, NSW Agriculture and the Queensland Department of Primary Industries. There were industry partners (40 commercial firms) and notably there were the 49 co-operating cattle breeders, and there was significant funding from Meat and Livestock Australia (originally Meat Research Corporation). There is basic research in genetics, nutrition, meat science, animal health and welfare, economics and waste management. Central to this CRC was the need to integrate the results so that Australia can be at the cutting edge. Perhaps the most significant output is the education and training of scientists, producers, managers and other end users. The CRC just didn't arise 'out of the blue', it must be seen as a continuation of these partners in their previous roles, but co-ordinated in such a way that those real commercial pressures can be considered in the outcomes.

I will review the general research trends in the past and the ones being undertaken now, focus on some key issues, explain the ramifications and challenge some current concepts and point to further opportunities. I will be drawing on recent CRC work that illustrates how useful such an organisation can be directing exciting and profitable research that bodes well for the future.

Animal production, processing and variation in meat quality

For Australia, meat production as we know it has only taken place over the last 200 years, as there were no resident animals in Australia with the right characteristics to farm. Some Australian Aborigine communities lived predominantly on fish and even developed fish farming (Diamond 1998). Farming of animals means that there is some control of production, with the potential for control of some desirable quality aspects — it isn't just harvesting and make-do with what we get.

There is a tendency to be apologetic about red meat and the division into red and white meats with the implication of health benefits is therefore rather artificial and often ill-substantiated. Meat is animal protein, which together with lipids form a valuable part of our diet. Sheep and cattle have throughout prehistoric times not only been a valuable source of protein, but also of products such as fat for candles and lubricants, hides, pelts and wool for clothing, which were almost of equal value. The final form of the meat protein was less important then, than the fact that it was obtainable. Now the markets are more critical and we need to produce meat of the highest quality to get improved financial returns.

Research focusing on animal production traits, such as growth and feed conversion efficiency, is obvious and is well understood — bigger, faster-growing animals mean more to sell. However, this does not in reality impinge on the consumer. The challenge has been to improve on this by tuning the adjunct processing to improve quality. This has been done in Australia and neighbouring New Zealand to some extent, although in both countries the full breadth of the opportunities available for improved meat quality are not necessarily recognised by the markets. One reason for this might be that one cannot tell the quality of the meat by its appearance.

The wholesale transference of carcass attributes of growth to meat quality is dubious at best. Every poster on cattle indicates that the particular breed displayed is tender, every breed society believes that its animals are the best, any experiment undertaken in one farming environment is invariably transferred to another and often from one country to another. This is done with the absence of proof, but with the philosophy that 'if the animal looks good then it must be tender.' The intensity of such a conviction has no bearing on the truth (Medawar 1981).

As many grading attributes (but not quality), such as marbling scores, are based on appearance, in a *de facto* way this has become a misguided meat quality indicator. It is untangling the web of production-based improvements and appropriate processing to meet market specifications (when the quality cannot be adequately measured) that still causes problems.

Meat variability and problems of meat storage become issues when meat is produced in one country and shipped to another country where it is consumed, especially in an affluent world with own-country loyalties. With such affluence, there is also an associated high level of criticisms if poor quality arises. It is in this framework we need to consider the effectiveness of Australian CRC research and its earlier contribution.

There is the recognition of the importance of animal welfare for productional efficiencies, the effect it has on meat quality and the potential for it becoming an issue for trade embargoes. The 3 underpinning components of meat quality, i.e. growth–efficiency, welfare–stress and processing–control, need to be considered together to obtain maximum benefits. While this is not an overt aim of the CRC, it requires an umbrella research program in place to do it. The understanding of consumer issues and using them in the final arbiter of meat quality means each sectorial view must now be backed by data.

CRC contributions to meat quality issues

The CRC environment allows the linkage between the production, including genetics and processing to be determined in a way that has credibility with all sectors. The results using about 10000 CRC cattle from a variety of genotypes and various production scenarios, indicates that there are minimal differences in tenderness if processing is in control and ageing is appropriate for each cut. This does not mean that a single identical processing situation covers all contingencies but consumers can clearly detect improvements in processing when they are achieved. There is clearly a need to dissect out the contributions that produce meat of the highest quality, from the various production–processing scenarios.

The concept of the Co-operative Centre for Cattle and Beef (CRC) is one area where the interactions of the various sectors can be determined (Fig. 1). Dealing with cattle from a wide variety of uncontrolled sources, with large difficulties in monitoring processing, has limited interpretations from experimental work over the years, where time, temperatures and muscle pH need to be known. The CRC programs have animals grown under controlled situations, either in a feedlot or a farm and where all aspects of growth and feed and stress are controlled in a way so that minor changes in processing can be revealed. This is most evident with the recent results from the CRC program (Dundon *et al.* 2000).

The CRC beef genetics subprogram has some of the leading researchers in the field identifying gene markers for production traits in livestock. Quantitative trait loci (QTL) comprise one or more genes whose genetic variation contributes to a significant amount of the variation in economically important production traits. While there is not a gene for tenderness *per se*, there is an average of 2.2 QTL per tenderness trait that account for up to 25% of measured variation (Hetzel and Davis 1999; Burrow *et al.* 2001). The research that characterises many meat and animal traits is fundamental to improvement. The QTL for meat quality therefore may be related to low stress situations that in turn may be reflected in tenderness improvements, faster growth rate, resistance to disease, marbling and fat colour, connective tissue and more complete adaptations to specific environments. Genetic improvements cannot therefore be considered on their own and would be part of an interactive program with meat quality.

The question one would ask is why is a merging of production and processing research and development necessary in a CRC environment in Australia, when there are large ongoing programs being undertaken in other countries such as the USA? It is true that all research is built on a body of knowledge obtained from many different fields and developed for other countries. However, such expertise may not necessarily be directly transferable to Australian conditions. It would be naïve to think that the production, transportation and processing scenarios in one of the driest continents in the world could be directly modelled on those from another country.

These comments would be especially true if that country had different procurement, finishing, processing, marketing regimes, subsidies that distort key items and an agricultural base that has a whole sector of the farming economy based on feeding corn — a feature significantly different to that of most other countries. In addition, the research and development base often has proprietary information pertaining to individual companies that is not widely disseminated and the production and genetic base is likely to

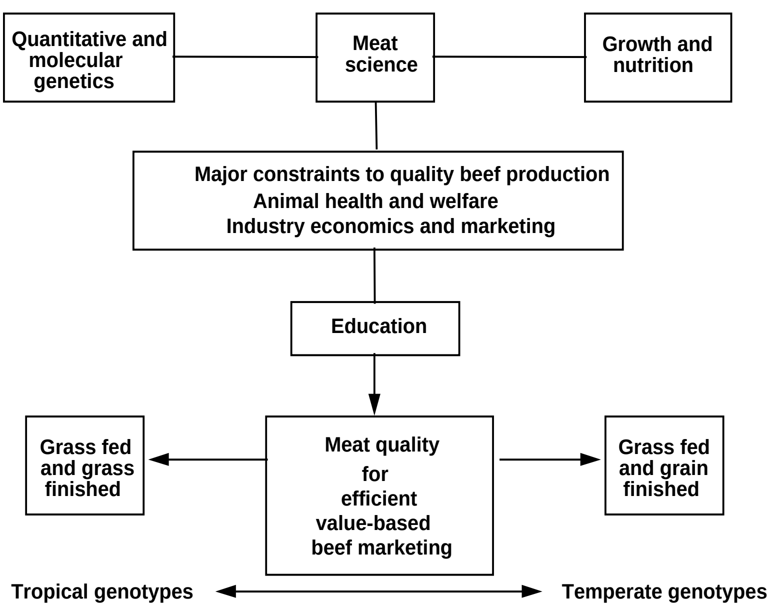

Figure 1. The interrelationships required to integrate a research program with all sectors of the beef industry. Diagram is from Hoppe (1994).

be different. In one example, genetic aspects are considered a major focus for improving meat tenderness (Miller *et al*. 1996), but the analysis focussed on 10 *Bos indicus* sires, with data only pertaining to these sires — such information is not really portable across countries. The identification of specific gene markers in this situation, however, may be extended more widely and such research in other countries still has a place. While *B. indicus* in the USA situations is reportedly tougher than *B. taurus* (Whipple *et al*. 1990), it may not pertain to the Australian situation where there is different genetic stock and where processing can negate these effects. Thus, breed and genetic issues need to be clarified and seen in perspective

Is marbling a meat quality issue?

The research into what is often regarded as meat quality in Australia has taken several paths. There has been a large focus on animal production, growth and efficiency and a focus to evaluate attributes such as marbling in beef (Rymill *et al.* 1997), resulting in conflicting views on a high degree of marbling as a meat quality attribute even in the USA (Dikeman 1996) and Canada (Jeremiah 1996). It appears that the eye of the beholder or eyes of the holder of the chequebook dominate interpretations on this aspect of meat quality.

Why have issues of marbling arisen? Some fat (intramuscular or marbling) is of course necessary for optimum palatability. In other situations, marbling may be visible evidence of a low-stress, well-fed animal and indicates good animal welfare — in such instances there will be an increase in meat quality merely from the low ultimate pH aspect. One also could easily come to the view that marbling may be required to ameliorate toughness by diluting the meat (which it sometimes appears to do successfully), compensating for poor processing and helping it slide down the throat.

As both the costs of production to produce marbling are high and wasteful of resources, the characterisation of optimum processing to produce a highly acceptable relatively lean product is desirable. Ironically, the lack of visible marbling in sheep and the absence of fat in the lean of venison, snakes, emus, ostriches, fish and shellfish, alligators, chickens and kangaroos is not seen as a disadvantage but rather is seen as a marketing advantage.

One needs to understand marbling and the genetics of marbling that is being undertaken in CRC programs. In this regard, the industry now has the ability to identify those sires that have the genetic potential to improve marbling. This has obvious benefits for that section of the industry devoted to supplying grain-fed beef into Japan. However, equally, we can also identify the higher-yielding, low-marbling sires that may be more appropriate for our domestic retail market.

Other aspects that contribute to overall palatability, such as tenderness and/or texture and juiciness, and that are arguably more important for meat quality are discussed below.

***Bos indicus* toughness?**

The calpain enzymes responsible for tenderness are ubiquitous in all animal species and are responsible in the living animal for tissue remodelling and are only fortuitously involved in a post mortem role. One therefore wonders why various genotypes have different levels of tenderness as all animals have to remodel their muscle tissues in exactly the same way. There have been several examinations of meat quality from various *B. indicus* and *B. taurus* experiments and the most recent is discussed here (Hearnshaw *et al*. 1998) from CRC studies. As the *B. indicus* content increased, the mean shear force was higher (or taste panel tenderness was lower), and in other studies, there was no difference depending on the cut examined. In general, the CRC studies have shown that meat from animals with inceasing *B. indicus* content are not as tender (but this should not necessarily be reinterpreted as being tough). The question we really need to ask is why is there less tender meat from various genotypes and why does it vary from one experiment to another? To damn a product through experimentation that merely notes a trait, rather than quantify its expression would seem counterproductive.

The small differences in tenderness (whichever way they go) between *B. indicus* and *B. taurus* are dramatically increased by poor processing treatments. In other words, if processing is for some reason below optimum, then all breeds were poor and often *B. indicus* fared worst for some muscles, but better in others. In reality, one should not consider a process that is known to enhance the worst aspects of all breeds. All optimally processed animals are highly acceptable in most studies (e.g. Hearnshaw *et al*. 1998) (Fig. 2). We would still like to know what is the animal characteristic responsible for this variation and whether it is related to preslaughter stresses or other factors? If there is this variability, why does it occur, how can we avoid it, especially when it is important for production reasons to develop animals otherwise well adapted to the Australian environment? In reality we need to view stress susceptibility, preslaughter management and processing as a continuum.

Biochemical studies

Meat is ‘dead’ muscle, but its final properties are dictated by the live muscle attributes earlier on in the meat’s history as well as effects from processing post slaughter. Studying the changes that take place, does not merely require examination of the meat, but an understanding of the breeding and genetics, pre-slaughter stress, the slaughter process itself, the various procedures such as electrical stimulation, the chilling–freezing conditions, packaging and distribution, consumer aspects and fat content (marbling). Tenderness is usually the issue considered, but usually when this is under control, so are juiciness, cook-loss, colour and other meat quality attributes.

The enzymes responsible for tenderness are the endogenous enzymes termed calpains, existing in two forms, responsible for protein turnover, with the process in the live muscle being inhibited by calpastatin (Dransfield *et al.* 1992; Goll *et al*. 1995). The proteins affected are not the contractile proteins of the muscle nor are they a component of connective tissue, but they comprise the structural proteins (e.g. desmin, titin and nebulin) within each muscle cell responsible for maintaining structural integrity. For these reasons, the calpain–calpastatin system, its regulation, degradation has claimed a great deal of attention, both internationally and in Australia.

In a simplistic view, it would be expected that high calpain–low calpastatin would be ideal to produce tender meat, but this concept does not always stand out in terms of experimental data and it would appear that too much emphasis is made of the relationships in terms of its quantitative effect. There is a very much greater difference in tenderness due to processing situations than due to levels of calpains. For example, with elevated *rigor mortis* temperatures about 35°C, the calpain levels are much lower than with *rigor mortis* at 15°C (Simmons *et al.* 1996). Indeed in the living muscle, calpastatin and calpains are compartmentalised so that their activity can be controlled and to some extent this remains so in *post mortem* meat. At the time the meat is ageing, the calpain levels are low and different from levels at slaughter (Simmons *et al.* 1996). This raises some serious doubts of the relevance of preslaughter calpain or calpastatin levels for predicting quality (or even whether it is relevant). A recent CRC study undertaken by McDonagh (1998) considers in some depth the calpain activity and protein turnover in animals in a variety of situations. He shows that calpain–calpastatin activity occurs in cold-shortened muscles that do not become acceptably tender, indicating that structural conditions can negate any processing advantage for tenderness and he also shows that the calpain–calpastatin ratios explain about 30% of post mortem tenderisation. The calpain levels might be indicative of potential meat quality, but only after first addressing processing variables.

Some causes of toughening and prevention — tenderstretch and electrical stimulaton

Tenderstretch

One major cause of toughening is shortening which initially toughens meat, but in addition, limits the tenderisation through ageing. One way of minimising the effects of shortening is to prevent it from happening, which was the idea behind supporting the carcass from the aitch bone. Under these conditions, the sarcomere length is significantly changed when the carcass is hung from the pelvis rather than the Achilles tendon and the meat is consequently more tender (Bouton *et al.* 1973, 1974; Hostetler *et al.*1976). This alternative hanging procedure, first patented in the USA, shows dramatic changes in tenderness in the most major muscles in the hindquarter. One procedure termed tenderstretch, results in significant improvements in meat tenderness as well as drip. If cold-shortening conditions are not imposed, it appears that the highest levels of tenderness are reached earlier and to a greater extent. Thus, a process using tenderstretch should be cost effective in terms of energy usage, confer a resistance to

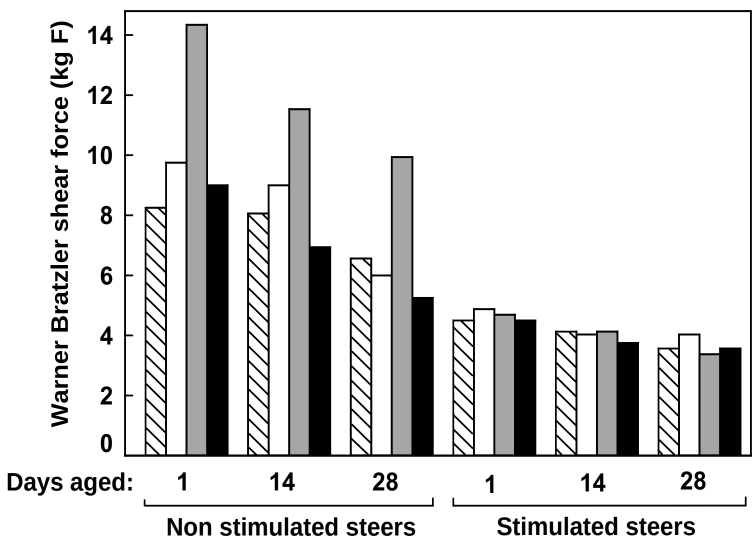

Figure 2. The effect of electrical stimulation and ageing duration on peak Warner Bratzler shear force of striploins from steers with varying Brahman content [0% Brahman (striped bars), 17–33% Brahman (open bars), 50% Brahman (shaded bars) and 67–100% Brahman (solid bars)]. Data are from Hearnshaw *et al.* (1998).

adverse chilling conditions and get meat to a market earlier and, thus, has fewer microbiological problems. It is being used in the UK Blueprint for meat quality and also in Australia under MSA.

The studies by O' Halloran *et al.* (1998) show that the meat actually starts off with a lower shear force (higher tenderness) value for tenderstretch that would be clearly beneficial in commercial terms regarding reductions in turnaround time (Fig. 3). That this process is not more widely used suggests that market pressures for a high quality product are not great enough yet, or perhaps electrical stimulation is believed to be the answer. This latter belief is only partially fulfilled as discussed below. Why does tenderstretch produce higher quality meat? The reasons are not yet clear, but it is likely that slightly longer sarcomeres confer an initial tenderness that is greater (Davey *et al*. 1967) and the enzymes responsible for tenderisation have less to do to reach a high degree of consumer acceptability.

Electrical stimulation

Electrical stimulation is the procedure of choice to produce tender meat as it is simple to do in an everyday context and, once it is up and running, comes nearest to the concept of a 'black box' of any procedure envisaged. The appeal of having carcasses being electrically stimulated is easy to visualise and sell as a working concept. Even so, it is only being taken up with reluctance. Australia was not the first country to develop electrical stimulation, but one of the few to use it for quality standards. The procedures were discovered by Benjamin Franklin, rediscovered by the Americans Harsham and Deatherage (1951) and Rentschler (1951), used for microbiological experiments (Ingram and Ingram 1955), rediscovered by New Zealanders (Chrystall and Hagyard 1976; Davey *et al*. 1976) and taken on board by Australia (Bouton *et al*. 1978, 1980; Powell 1991) and New Zealand (Chrystall *et al.* 1983). The initial electrical stimulation studies were designed to get the greatest effect and this entailed high voltages (about 1130 V peak in some New Zealand systems) being used and defined pulse frequencies. It also meant that worker safety became paramount. Electrical stimulation became much less effective when low voltages were used, but if applied before the nervous system became inactive, it worked. This formed the backbone of the Australian 'effective low voltage stimulation systems' employed with working voltages of 40 V peak. The Australian industry has pursued both high (e.g. Powell 1991) and low voltage systems (e.g. Bouton *et al*. 1978, 1980) that are used in Meat Standards Australia, and are designed to produce a guaranteed eating quality.

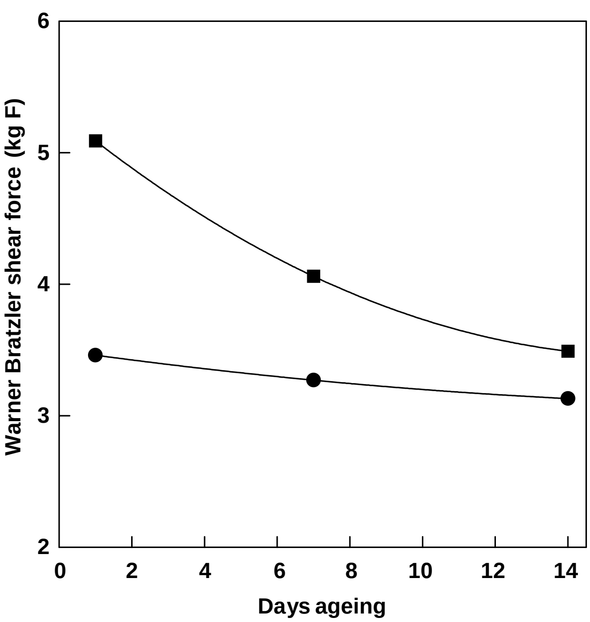

Figure 3. The changes in shear force versus days ageing for tenderstretch (●) and normally hung (Achilles suspension) animals (■). Data are from O'Halloran (1998).

Amount and time of stimulation

There could be a lingering suspicion that if a little electrical stimulation is good, then a lot could be better. It is becoming clear that this is not true and an optimum electrical stimulation process needs to be in place. This was not initially obvious, because the early electrical stimulation systems made such a dramatic improvement, that the fine gourmet standards weren't even considered. However, as the consumer has become more discerning and the research approach changed, subtle but significant improvements have been found when optimal stimulation is used.

What is optimal? Recent studies (Hwang *et al*. 1998) showed that merely stimulating a carcass does not offer all the advantages of stimulation. A delay of 30 min before stimulation, whether high or low voltage, was actually found to be better in terms of tenderness than stimulating early at 3 min. While it is contrary to the way of thinking a few years ago, there is other evidence that delays produce a better effect. The reasons for this are unclear, although one viewpoint is that the temperature of rigor has an effect on tenderness (Devine *et al*. 1999) and this is indirectly influenced by cooling and hence time of stimulation (Wahlgren *et al.* 1997). However, the differences between 3 and 30 min will only result in small differences in rigor temperature, so other factors dominate. Understanding these differences will lead to more efficient and better stimulation.

Pre-slaughter stress and welfare studies and implications for meat quality

Stress is almost invisible, we really can only determine extremes through changes in gross behaviour patterns, or determine whether moderate stress has been imposed before observation by the effects it produces. For meat, the impact of pre-slaughter stress is manifest through an increase in the ultimate pH and consequent increase in microbiological spoilage in vacuum-packed meat. Fresh meats spoil in air due to the growth of Gram-negative bacteria; thus, vacuum packaging of meat has evolved to increase the shelf life, as lactic acid bacteria can now grow to the exclusion of others. Lactic acid bacteria grow utilising sugars and carbohydrates in the muscle. As the pH elevates the conditions are more favourable to other types of bacteria, including Gram-negative bacteria, which utilise amino acids with the resulting by-products contributing to spoilage (Egan and Shay 1988; Fabiansson *et al.* 1988).

Howard and Lawrie (1956) showed in Australia that by chasing the animals on horses, it was difficult to elevate the pH of cattle unless they suffered nutritional problems at the same time. This investigation only really studied one kind of stressor, that of exercise. When additional stressors were superimposed on exercise, such as transport over long distances and animal mixing, then the pH was elevated (Wythes and Shorthose 1984). Shorthose (1977, 1978) extended such work to sheep and was one of the first to show the effects of stress on tenderness and other meat properties. It is clear that stress was having a large effect on meat quality through elevation of meat ultimate pH.

The most confusing and troublesome aspect of ultimate pH on tenderness is that it is an inverted U relationship — both high and low ultimate pH values produce tender meat, whereas meat of an intermediate pH value (pH value about 5.9–6.0) is tougher (Bouton *et al*. 1971; Purchas 1990). Most importantly, the increases in toughness climb dramatically in the ultimate pH range 5.5–5.8, which is the range of ultimate pH values we normally observe in commercial cattle (about a 50% increase in shear force in unaged meat). In other words, the animal stress we normally encounter accounts for a disproportionate amount of tenderness variability. Not only does stress affect tenderness, but the elevation of ultimate pH affects the denaturation of myoglobin during cooking, making it difficult to achieve a reproducible degree of doneness (appropriate colour) in the food service industry (Cox *et al.* 1994).

Although elevated pH meat can age in some temperature regimes to become tender, in others circumstances it does not. The question we must additionally ask is why are some animals stressed, while others are not? Can we change production or breeding to produce an animal resistant to reasonable levels of stress? This is a challenge that requires research approaches to monitor biochemical and neurological stress changes over times of greatest susceptibility. It would be necessary to use simple measurement techniques on large numbers of free-ranging animals to determine individual changes in individual animals (i.e. to detect outliers). It is possible, that placing an animal in a relatively constant environment in a feedlot accomplishes some of the desirable changes, but one cannot say it is a cheap option.

There is another dimension to stress and that is the invisibility of it, and thus it is often ignored. Stress is usually revealed some time after it happens, through lower pre-slaughter muscle glycogen, but the effects lie deeper than this. A recent study (Butchers *et al.* 1998) through the CRC showed that animals with the same ultimate pH values, originally from the same feed lot, and thus regarded as well fed and familiar with humans, were processed by different avenues. One group of cattle were transported to a feedlot at the processing plant several days in advance of slaughter and made their way from the holding pens in a very relaxed manner on the day of slaughter. The other group was trucked to slaughter as normal and fasted overnight. The fastest rates of glycolysis occurred in the low stress and rested animals and those with optimum stimulation (Table 1). The tenderness was similar for the low stress, unstimulated animals and the stimulated fasted cattle. The unstimulated fasted cattle, however, were significantly tougher. This unexplained difference in toughness between processes that should have produced a high quality product occurs often. It is clear that toughness was not a result of cold-shortening or ultimate pH changes, and must lie elsewhere. One possibility is that pre-slaughter stress has effects on metabolism other than merely elevating ultimate pH, and produces a wider range of effects than initially envisaged. Such effects of

Table 1. Interactions between pre-slaughter handling and electrical stimulation

There were 10 animals in each group; the control animals were in a feedlot about 100 m from the slaughter plant and merely had to walk gently to the plant to be slaughtered; the fasted animals had been transported from another feedlot (from which the control animals were originally sourced) and held overnight and fasted as is normal practice; the pH falls of the control unstimulated animals was almost as fast as the stimulated animals; with the longest stimulation the fasted animals had the most rapid pH fall; only the longest low voltage stimulation produced meat as tender as the control unstimulated, but all stimulated meat was tender; tenderness score: 0, very tough; 100, very tender; data are from Butchers *et al.* (1998)

Treatment	pH at 3 h		Warner Bratzler peak shear force (kg F)		Panel tenderness score	
	Control	Fasted	Control	Fasted	Control	Fasted
No stimulaton	6.01	6.33	4.48	8.8	48.5	26.5
10 s stimulation	5.97	5.57	4.60	7.1	48.3	38.9
40 s stimulation	5.50	5.48	4.80	4.7	41.9	44.2
Mean s.e.	0.08	0.08	0.60	0.6	4.1	4.1

pre-slaughter stress are under-resourced, but with a great potential for improvements in meat quality.

The real test — using the consumer

Consumers have been inundated by claims from breed societies, supermarkets and butchers and, up until now, have no real base on which to make a purchase. It is now time that facts be used as a way to classify cuts and provide cooking instructions on the label. The Meat Standards Australia (MSA) grading scheme developed by Meat and Livestock Australia has used domestic consumers to test the product from various processes, cuts and breeds and is focussed on guaranteeing eating quality to consumers. It was not developed by the CRC, but draws on the outcomes of CRC research as well as the expertise of its staff. MSA uses a total systems approach by controlling factors that impact on meat quality from the production, processing and value-adding sectors of the meat production chain, rather than relying solely on carcass assessment. It would be fair to say that it is the culmination of all the research undertaken by the Australian meat industry, with other important aspects gleaned from researchers elsewhere. MSA is not the first system to focus on the consumer and reflects the worldwide trend to provide a better quality product such as New Zealand Beef and Lamb Quality Mark and Blueprint for eating quality in the UK and those being developed in other countries. It is structured to take account of future research inputs.

The MSA grading scheme uses principles of Palatability Assurance at Critical Control Points (PACCP) developed earlier in the USA and is based on consumer scores that were used to set grade standards (Polkinghorne *et al.* 1999). The 4 sensory dimensions (tenderness, juiciness, flavour and overall acceptability) were combined into a meat quality score (MQ4) that was then used to calculate boundaries for '3-star', '4-star' and '5-star' grades. Outliers were minimised by statistical procedures to produce a CMQ4 score. The total consumer responses, using 5 cooking techniques (grilling, roasting, stir-fry, slow cook and corning) were in excess of 100 000. The scheme will eventually be extended to the export markets. The MSA grading system is aimed at describing the eating quality of the retail product in a simple language that is easily understood and interpreted by the consumer. The system provides a star rating on eating quality and advice on how to best cook the product.

Perhaps the most significant aspect of the MSA system is based on the concept that eating quality of meat is a function of all the processes that have occurred in the production (Thompson *et al.* 1999*a*), pre- and post-slaughter, processing (Ferguson *et al*. 1999), type of cut and cooking method (Thompson *et al.* 1999*b*) phases involved in putting a steak on the plate. It was clear that, with the present processing options using 3 grades with eating quality, data collected by MSA has shown differences in *B. indicus* content using consumers, especially for the *psoas*, *M. longissimus dorsi*, but this did not necessarily apply to other muscles. Furthermore, the differences are significantly reduced by optimum processing, especially ageing. The goal would be to find processing options that could reduce differences even more. Perhaps the most significant aspect of the MSA system is that it is based on customer perceived quality, it is continually evolving and it can be tailored for consumers anywhere. While MSA offers exciting opportunities for the beef industry, it is apparent that widespread adoption of the system will take more time than first envisaged. This is unfortunate; however, some solace can be gained by the fact that bringing about quantum changes in product differentiation was never going to be easy.

Conclusions

The research into meat quality in Australia must be Australian driven, but this can only be done when there is confidence that the research is going in the right directions and guided by those who really understand it. Meat science is not only difficult to do because of sheer logistics, but also because of cost and in some circumstances, the skills and depth of knowledge required would not be out of place in a medical research laboratory.

It would be fair to say that the producer, processor, marketer and consumer do not always have the same goals (mutual misunderstanding) that reduces the overall rate of uptake of technologies and process implementation.

Because the lead times are often so great, the research to provide the 'desired' marbling of today may well only be reached when such market demands are eventually not tolerated in the future because of agricultural resource limitations; thus, we need to be adaptable for future demands.

As we see and eat meat everyday, we often underplay its characteristics and are not aware of its imperfections. The cook is often blamed rather than the processor, if any imperfections appear. We would not tolerate such variability in any other product that I know of! The nutritional advantages of meat, such as the content of iron, omega 3 and omega 6 essential fatty acids, need to be stressed.

Because meat quality cannot be determined from the meat's appearance, meat quality is guesswork tinged with some process control. The future development of a non-invasive instrument to determine meat tenderness is required.

It is all too easy to glimpse some research elsewhere in the world without being critical of it (see quote at beginning of this paper), especially if it purports to meet a requirement, however poorly. Australia has been well served by its scientists and the model of the Cattle and Beef CRC is an extension of the excellent earlier work. It will enable the various sectors to work together for significant future improvements.

It is often thought that much of meat science is already known, but this is just not true. There are many areas, especially in the effects of stress on meat quality and the way nitric oxide affects tenderness (Cook *et al*. 1998) (apart from the chemical's other roles that gave its researchers a Nobel Prize) that may change our approaches to controlling animal stress and modify processing situations.

The new MSA grading system, an Australian concept, is aimed at describing the eating quality of the retail product in a simple language. It is based on the concept that eating quality of meat is a function of all the processes before putting a steak on the plate and will naturally evolve, based on future studies. Such a concept will improve eating quality for the consumer and for export markets and should not be subverted by vested interests. It should not be static and should evolve to meet future market requirements.

While one would eventually expect industry to respond with research undertaken by the CRC, whether they are partners or not, vested interests may prevent this taking place quickly. The response time needs to be fast in order for the Australian meat industry to remain ahead. Further research will clarify and simplify many of the difficulties and quality assurance issues for beef supply chains — there is a role for CRC, MLA and the industry in further education initiatives

Australia is unique and the meat industry reflects it. It is necessary for all sectors of the industry to work together to use research and if necessary challenge non-scientific current thinking, whether from Australia or imported from elsewhere. In other words, Australians should believe in themselves and their own work.

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