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Processes for Measuring, Communicating and Valuing Eating Quality and Saleable Meat Yield in the Australian Beef Value Chain: Current Status and Future Opportunities

Doljanin, I.A., Thompson, J.M., Griffith, G.R. and Fleming, E.M.

Doljanin, I. A. Business Manager, Allflex Australia, Toowoomba, QLD and formerly Postgraduate Student, UNE Business School, UNE, Armidale, NSW
Thompson, J.M. Adjunct Professor, School of Environmental and Rural Sciences, UNE, Armidale, NSW
Griffith, G.R. Professorial Research Fellow, UNE Business School, UNE, Armidale, NSW, and Principal Fellow, FVAS, University of Melbourne, Parkville, VIC
Fleming, E.M. Emeritus Professor, UNE Business School, UNE, Armidale, NSW.

Abstract

Over the past 20 years, the Australian beef industry has developed world-leading consumer grading technology, Meat Standards Australia (MSA), to predict the eating performance of beef meals more consistently. The traditional measure of meat quality has largely been associated with increased presence of intramuscular fat, or marbling, to enhance flavour, juiciness and tenderness. The research collated by MSA demonstrated the interconnectivity of pre and post-slaughter treatments with the traditional measurements of marbling, intramuscular fat and ossification on consumer palatability scores. Yet, in beef pricing systems, quantity measures are based simply on carcass weight, not the yield of saleable cuts from this carcass.

Meat quality- and quantity-based pricing should provide incentives and disincentives to producers based on traits that demonstrate repeatability and effectiveness over the longer term. This will ensure decision-making can result in improved outcomes. Establishing an effective pricing methodology incorporating both eating quality and carcass yield will address the century-old lack of progress because value chain components are studied in isolation when in reality they are part of an integrated system. Efforts should focus on a common end point – a consumer-focused product.

Implementing a process of traceability throughout the value chain and incorporating an eating-quality and saleable-meat yield-focused payment for carcasss can achieve three complementary objectives: (1) deliver a product tailored to consumer needs; (2) address traceability concerns to guarantee food safety; and (3) accurately communicate carcass yield and quality combined into one payment scale that can be used to facilitate improvement throughout the beef value chain. The potential of this system is to create an integrated value chain optimised for whole chain profitability.

1. Introduction

Australia is the world's second largest exporter of beef, exporting over 60% of the 2.3 million tonnes of beef and veal produced in 2013/14 to over 100 countries around the world (ABARES 2013, MLA 2014). While accounting for less than 4% of the world's beef supply, Australia provides about 21% of the global export market for beef. Thus, improvements in the production and marketing systems for Australian beef have implications for many other beef industries around the world.

The development of the Meat Standards Australia (MSA) grading model (Thompson 2002, Polkinghorne et al. 2008b) represents the best existing total quality management approach for improving beef quality and palatability (Smith et al. 2008). This modeling tool seeks to predict consumer satisfaction at a cooked portion level (Polkinghorne and Thompson 2010), moving the beef industry from describing carcasses to describing individual beef meals (Polkinghorne and Thompson 2010) thereby providing a more accurate description in terms of what the consumer requires and values.

Ultimately, it is the consumer's purchasing decision that determines the gross income available for distribution to each participant throughout the beef value chain (Polkinghorne 2006). Unfortunately, payments between participants within the Australian beef value chain are characterised by poor price communication (Gong 2008). Polkinghorne (2006) argued that "payment and description at each end point of supply have at best, a very poor relationship to consumer satisfaction". To address this shortcoming, it is important first to identify the variables from each component of the meat production process, namely on-farm animal characteristics, abattoir processing variables and consumer preparation methods. The interdependence between these variables had been identified more than 50 years ago by Butler (1960), Friedlander (1964) and Everitt (1966), and has been more thoroughly quantified in recent times during the development of MSA. This interdependence is now known as a Palatability Analysis Critical Control Points (PACCP) pathway (Ferguson et al. 1999, Polkinghorne et al. 1999, Thompson et al. 1999a,b, Thompson 2002, Polkinghorne 2006, Watson et al. 2008).

While the development of MSA has been a great leap forward, much more can be done. The challenge is two-fold. The first challenge is to maintain traceability of knowledge throughout the value chain to the primal when it is in a carton with other primals, so that it may be used as a marketing tool to help differentiate quality and salient credence attributes of each primal, thereby increasing revenue.[1] This would be a small but significant step in the progression toward a value-based trading system. Second, this information needs to be related back to the live animal, so that management decisions can be made at the production level to meet market specifications more accurately, allocate resources effectively and reduce costs.

2. Literature Review

While significant research has been performed into all the individual aspects of the beef value chain, it has been problematic to link them all together. While factors such as reproductive efficiency and feed conversion are obviously important in the production system, saleable-meat yield percentage (SMY%) and meat quality are the two post-farmgate factors that ensure the long-term profitability and sustainability of the beef industry. This review will focus on how participants currently measure, communicate and value eating quality and SMY% throughout the beef value chain and what could be done to improve the current process.

[1] A more logical alternative would be to sort into quality ranges, hence obviating the need for full traceability.

The prevailing industry paradigm is that the level of difficulty and associated costs to achieve individual cut traceability are prohibitive. Therefore, the research and development focus has been on studies that attempt to predict the quality and yield of the carcass with connection to the live animal. Measurements taken on the slaughter floor, kill chain and/or at the point of chiller assessment are used in a number of ways, endeavouring to predict the components that will be generated from the carcass. This focus has largely been driven by the now outdated paradigm that beef quality can be judged at the carcass level. We now know that beef quality varies at the primal level and even within the primal, based on the cooking method being used (Polkinghorne et al. 2008b).

A new paradigm of traceability is becoming apparent throughout the value chain using the advances in processing systems, computers and the supporting technology of barcodes and radio frequency identification. Processing facilities have become larger, more automated and throughput-focused to decrease unit overhead costs. They have also maintained or increased the level of traceability. Traceability was originally driven by food safety concerns and regulations, although increasingly it is now being driven by recognition of the inherent differences in quality and yield of primals. Advancements in traceability will ultimately facilitate the communication of value throughout the value chain.

The following review covers five main areas of discussion: (1) measuring proportions of muscle, fat and bone; (2) current methods of valuing meat quality and yield; (3) communicating value between chain participants; (4) a processing case study of Polkinghorne's value chain in Australia; and (5) effective beef value chains.

2.1 Measuring proportions of muscle, fat and bone

There has been a long history of scientific endeavour to characterise and predict the proportions of muscle, fat and bone that are generated when the carcass is boned. Early research conducted by Murphey et al. (1960) was the basis of the United States Department of Agriculture (USDA) yield grade calculation that is still in use today. Johnson (1996) reviewed previous research, as outlined in Table 1.

Various combinations of carcass weight, subcutaneous fat (at 10/12th rib, or P8 or both) and a third regressor were investigated to explain three measures of carcass yield percentages, namely estimated lean beef yield, carcass meat and SBY. Research performed by Crouse et al. (1975), shown in Table 1, highlights the regression equation developed by Murphey et al. (1960), which was the most accurate of those listed before 1989; hence its use as the basis for the USDA yield grade calculation.

Logic leads us to identify the yield of saleable meat as an important contributor to carcass value. Ball and Johnson (1989) demonstrated a positive correlation between carcass fat percentage and SBY percentage. Because SBY percentage was being affected more by the percentage of fat than by the percentage of muscle in the carcass, Johnson (1996) contended it was "likely to be of limited value to genetic improvement". Instead, Johnson advocated the measures of estimated lean meat yield and particularly carcass beef proposed by Charles (1977) to address confounded comparisons of yield because of the differences in the composition of muscle and fat. This proposal supported earlier calls by Everitt (1966) for "fat-corrected" carcass information. Despite these limitations, SMY% has remained the preferred measure of carcass yield.

Other measures that reflect carcass yields have been investigated. Murphey et al. (1960) theorised that the percentage of kidney fat might be correlated to the amount of intermuscular fat. Murphey et al. (1960) and Crouse et al. (1975) found that subcutaneous rib-fat measured at the 12th rib was the most useful measure to predict carcass yield.

Dikeman et al. (1998) found that intermuscular fat accounted for twice the variation explained by subcutaneous fat, confirming an earlier study by Seebeck and Tulloh (1968). However, measuring intermuscular fat currently requires the full seaming of muscles and is impractical for a commercial processing facility. Further developments using x-ray technologies such as computed axial tomography (CAT) scanning or Dual Energy Absorptiometry (DEXA) could be a viable alternative.

There has also been significant effort directed to establishing predictive relationships between the measure of one muscle and overall carcass yield. Orme et al. (1960) reported a 0.96 correlation coefficient for the weight of *M. biceps femoris* and the total weight of separable carcass yield and estimated a regression equation that explained 92% of the variation in total separable carcass lean meat. Lunt et al. (1985) developed a two-variable equation of adjusted fat thickness and *M. biceps femoris* that accounted for 88% of the variation in predicting the weight of lean meat on a carcass. Unfortunately, obtaining this muscle weight in a normal boning process is very difficult because a muscle such as the *M. biceps femoris* is in two primals, the silverside and the cap of the rump. Collecting this information requires a detailed carcass dissection that requires care and is relatively slow, labour-intensive and therefore very expensive. Despite good predictability, the practicality of obtaining the information needs to be carefully considered to facilitate uptake of the technique. In addition, smaller muscles have a greater surface area to volume ratio and therefore are more prone to trimming errors.

Table 1*: Residual standard deviations in the estimate of percentages of muscle (Muscle%), fat (Fat%) and saleable beef yield (SBY%)

Source	Carcass traits	Muscle %	Fat %	SBY %
Crouse et al (1975)	CW + FT12 + EMA + KP Fat	N	N	1.79**
Charles (1977)	FT12	2.51	2.98	2.85
Kempster (1978)	Fat Class + CW	N	N	1.84
Johnson and Davis (1983)	FT10 + CW	2.11	3.00	N
	FT12 + CW	2.12	2.70	N
Ball and Johnson (1989)	P8	N	N	2.26
	FT12	N	N	2.14
Ferguson (1989)	P8	2.98	3.10	2.13
	FT12 + CW	2.71	2.45	1.97
Johnson and Ball (1989)	P8 + CW	N	N	1.46

**Reproduced from Johnson 1996, sources cited therein*

Abbreviations: CW = carcass weight; EMA = eye muscle area; KP fat = kidney + pelvic fat; P8 = fat thickness at rump P8 site; FT10 = fat thickness at 10th rib; FT12 = fat thickness at 12th rib;

** Standard error of estimate of the mean (%) N = not measured

Studies conducted by Berg and Butterfield (1966) found that muscle distribution was relatively fixed and conformation was altered by muscle shape and fat. More recently, studies in Europe by Conroy et al. (2010) assessed the ability of the EUROP classification system for carcass conformation and fatness (scale 1 – 15) to predict the proportions of meat, fat and bone in the carcass. This resulted in 73%, 67% and 71% explanation of variance in the proportions of meat, fat and bone respectively. This was not as accurate as the combined measure using hindquarter meat (13 cuts generated from an 8-rib pistola), which explained 93%, 87% and 89% of variance in the proportions of meat, fat and bone respectively, but the latter measure is much more laborious and painstaking to collect. Given the trade-off between accuracy and time, it is envisaged the Irish beef industry will look to combine the EUROP classification with a video image analysis process to implement more effective payment systems based on meat yield without incurring the cost of whole carcass dissection (Conroy et al. 2010). Again, the practicality of obtaining the information is a major consideration to be effective in large-scale operations.

The USDA (1997) yield grade is a good indicator of carcass yield. Cannell et al. (2002) reported that the correlation ranged from 0.39 using online graders operating at chain speed, 0.67 for expert yield graders with unlimited time to assign a yield grade and 0.65 for a combined system of video image analysis and grader input. Shackelford et al. (2003) reported that using the MARC video image analysis system to assign USDA yield grades had a correlation of 0.90 of the yield variance.

Three video imaging systems trialed in Ireland explained 84%, 85% and 87% of the variation in percentage yield (Allen and Finnerty 2000). Yield grade information needs to be accurate and significantly explain the variation of yield to be useful, but it is not cost effective to give graders unlimited time to obtain the information.

The Australian industry is characterised by abattoir feedback identifying gender, dentition, hot standard carcass weight and subcutaneous fat measurement at the P8 site. Sometimes, this also extends to chiller assessment details on intra-muscular fat (IMF), meat colour, fat colour, eye muscle area (EMA) and rib fat (usually at either 10th, 11th or 12th rib). This information is often used by processors as a selection tool to sort products for marketing and is therefore easier to provide as feedback. While providing this feedback to producers may be deemed cost-effective by processors, it needs to be reliable and consistent. As highlighted above, the proportion of explained variation ranged from 39% in the estimation of yield by graders at chain speed (Cannell et al. 2002), 84 – 87% for yield assessed by video image analysis (Allen and Finnerty 2000) or 73 – 93% for meat by classification or classification and dissection in the study by Conroy et al. (2010). Feedback needs to be provided in a way that enables selection of higher performing animals while being cost effective. This underlies the move around the world to integrate computer-based measurement systems with graders to provide objective, repeatable data collection for more accurate calculation of yields at plant speed rates.

Johnson and Chant (1998) highlighted the technologies being used to improve the accuracy of carcass yield prediction. These technologies were listed as real time ultrasound, velocity of sound, bioelectrical impedance, video image analysis and carcass density. Only video image analysis appears to remain in use on a commercial scale and even its uptake has been relatively limited. The move to more objective measurements rather than subjective human appraisal of carcass traits is driven by a desire to establish performance-based pricing schedules. For these systems to be effective, there needs to be consistency in carcass classification to obtain the confidence of participants (Allen and Finnerty 2000).

In the research for accurate representations of carcass muscle proportions, the common threads have been that the measurement of traits needs to be reliable, rapid and inexpensive to collect (Crouse et al. 1975, Lunt et al. 1985) without “disrupting the normal product flow” (Gardner et al. 1997). While this might be relevant to the processing sector, this paradigm needs to be challenged in the context of the entire value chain. The cost of collecting this information can be mitigated by the savings achieved through more effective resource allocation preventing over-fat carcasses and improving yields of saleable meat within the confines of functionally efficient animals.

Since the work of Murphey et al. (1960), it is now more than 50 years since these yield relationships became quantified and an effective system of communicating yield throughout the value chain has yet to be implemented. Despite receiving some information on yield grade, it is defined in different ways that make it impossible to compare between processors accurately. It is also often inconsistent between kill days within the same facility. This leads to information being provided as feedback that is unreliable for making selection decisions.

The scientific community largely agrees on the methodology of estimated lean meat yield and carcass beef measures, but the commercial application as a tool for payment to producers has not resulted. It appears that these measures are confusing to producers and not easily communicated. None of the large-scale manufacturers has been willing to risk upsetting their supply lines by acting alone to bring about such a change. On the other hand, the term “saleable meat” has some resonance at every level of the value chain. As discussed earlier, if the definition of “saleable meat” was standardized as lean meat yield, it would have more traction as a management/genetic tool for producers to improve carcass yield.

In summary, the beef industry at large has become efficient at following a process that is fundamentally flawed due to the limitations and self-imposed constrictions on the flow of relevant market information. Until this is addressed, only relatively minor incremental improvement will continue to be made while the terms of trade relative to other protein sources such as chicken and pork continue to decline due to their increasing production efficiency. Given this is such a fundamental driver of value, what has been the cost of not providing appropriate feedback? What has been the opportunity cost of restricting genetic improvement?

2.2 Current methods of valuing meat quality and yield

Australian meat yield is largely communicated through price variations surrounding hot-dressed carcass weight and hindquarter (P8) fat measurements in grid pricing schedules. The ranges quoted are usually so large as to address only the extreme variation in yield, either very fat or very lean. Quality is usually included by overlaying premiums or discounts for marbling scores.

Ferguson and Thompson (1995) found that the payment grids based on weight, fatness, dentition and marbling perform poorly at predicting individual carcass value realised in the boning room. They examined the ability of commercial market grids to predict carcass value within five different categories which included cow, Korean grassfed, Domestic grain fed, Japanese grassfed and Japanese grainfed (150 days). Using the company's current wholesale values for each of the trimmed boneless primals, manufacturing trim, fat and bone, the $ value was multiplied by their weights and then summed to calculate realised value in $/kg. Similarly, current market grids were used to calculate the grid price for individual sides. There was no relationship between realised value in the boning room and grid value (ie what the producer was paid) for each of the five categories.

Perhaps this was not surprising as individually the traits in the grid (such as weight, fatness, meat colour, marbling, and dentition) have only a low relationship with realised value. This low relationship for individual traits with carcass value was further eroded by using a grid payment system to categorise the input traits into weight, fatness and marbling classes. Clarke et al. (2009a) concluded that "…there was limited information quantifying carcass value to beef producers" and Polkinghorne (2006) argued that "… payment and description at each end point of supply have at best, a very poor relationship to consumer satisfaction".

The MSA grading system provides a tool to feedback eating quality information to the producer. The MSA grading system is driven by an empirical model (Watson et al. 2008), which generates a numerical score for individual cuts by cooking method from a series of commercial inputs describing the animal and its treatments. The numerical score ranges from 0 to 100 and is calculated for each cut of meat, such as knuckle, striploin, topside or tenderloin. MSA delivers a score for six cooking methods for each muscle that can result in one of four grades (Polkinghorne et al. 2008a): Ungraded <45.5, 3 star 45.5<63.5, 4 star 63.5<76.5, and 5 star >76.5. The score is based on a discriminant function using tenderness, juiciness, flavour and overall liking scores to predict grade (Watson et al. 2008).

The MSA grading system was designed to address the poor ability of the different grading systems around the world to predict beef eating quality. Currently, in Australia, processors only use MSA to distinguish whether or not carcasses achieve the base MSA qualification and maybe one other higher quality group, paying producers and charging customers accordingly. It is unclear how much revenue is being forgone due to this incompletely satisfied demand.

Unless Australia fully embraces MSA, the marketing of meat to address consumer expectations is flawed. Even with the current acceptance of MSA, the Australian industry values consumer preferences so broadly that it is ineffective in identifying better performing animals, thereby stifling genetic improvement. This explains the inability of the beef industry to make any significant productivity gains in meat quality or yield (but also means the opportunity is still available to do so).

Producers are able to access MSA feedback for individual carcass traits including carcass weight, rib fat, MSA marble score, ossification score, HGP status, hump height and sex. However, because the equations used to predict eating quality vary for each muscle, it is difficult to assess the importance of these individual traits on eating quality across the carcass. More recently, the "MSA Index" has been developed which combines the impact of all these inputs and allows producers to evaluate changes in their business, to drive a faster rate of gain in eating quality.

The MSA Index assumes a standard muscle distribution pattern in all carcasses (Berg and Butterfield 1976). The proportion of each muscle relative to the whole is then multiplied by the eating quality score for all 39 muscles in the MSA output. These proportions are then summed which in effects calculates a weighted MSA eating quality score for each carcass (Anon 2015).

The MSA Index only takes into account those animal factors in the MSA model that are under the producer's control and include *Bos indicus* content, sex, hormonal growth implant status, hot carcass weight, marbling and ossification scores and rib fat depth. Ultimate pH may be influenced by both the producer and the processor and so it is standarised at 5.5. Similarly, carcass hanging and ageing effect are also under the control of the processor and so the MSA Index is calculated assuming that the carcass was hung by the Achilles tendon and all cuts were aged for five days. The most common cooking method is assumed for all cuts.

For the first time the MSA Index provides a consistent benchmark which can be used by producers to benchmark processors, geographic regions and changes in management and genetic practices over time. It reflects the impact on eating quality of management, environmental and genetic differences between cattle at the point of slaughter.

Less progress to improve eating quality has been made in other countries. In the United States, animals are largely purchased on eight quality grades administered by the USDA. These grades are listed in order of highest to lowest quality: Prime, Choice, Select, Standard, Commercial, Utility, Cutter, and Canner. Five yield grades (1-5) are also used on a voluntary basis. The yield grades were originally defined by the *Federal Regulations 1965*, and more recently the USDA *Standards for Grades of Slaughter Cattle and Standards for Grades of Carcass Beef* (USDA 1997). Despite this system having the right intentions, a recent review found the USDA system to be relatively ineffective at predicting quality or yield with sufficient accuracy (AHDB 2008).

The classification system in the United Kingdom uses EUROP to make yield estimates and assumes that carcasses produced within industry blueprint guidelines will have cuts of similar eating quality. This combination of yield and blueprint production creates carcasses of uniform value. While the United Kingdom has quality-based pricing in the industry, the current approach is regarded as “only partially successful” and rarely links to “strategic supplier improvement” (Hines et al. 2006).

2.3 Communicating value between chain participants

Akerlof (1970) argued inter alia that if good quality products cannot get a price premium, only bad quality products will be offered for sale. Worse still, the genetics for providing good quality product are sacrificed; therefore, it is vital that correct information be disseminated throughout the value chain. Beef value chains are most effective when the participants are aligned toward a common outcome and extract maximum revenue from their value propositions. The expectations of the final consumer are crucial because the amount of money for distribution throughout a value chain is determined by the value perceived by the end-user and the price they are prepared to pay. In order to maximise this revenue, effective communication between the participants in the value chain is essential.

In a report to the New Zealand Meat Producers' Board, the Meat Export Grades Investigation Committee (1965) were quoted by Everitt (1966, 269): "Efficient grading results in the producer being rewarded for the production of the grade of meat in greatest demand at particular times and in particular markets, and allows the product being bought on its grade mark without inspection". To achieve this result, communicating meat eating-quality and yield throughout the value chain should focus on representing consumer value to all participants. The optimal result would remunerate producers in a way that effectively represents the return the animal makes for the processor and all stakeholders within the process.

The three key components of the meat production process are on-farm animal characteristics, abattoir processing variables and consumer preparation methods. MSA modelling supported earlier work by Butler (1960), Friedlander (1964) and Everitt (1966) by finding that these components are interdependent (Watson et al. 2008). Despite this interdependence, anecdotal evidence suggests the provision of feedback to producers from the processing sector is considered to be a cost. This attitude results in only the minimum feedback being provided with little regard for its relevance, constraining the suppliers' ability to raise the prices received for their products.

This poses a dilemma for most processors. In theory, a processor aims to maximise profit by setting marginal revenue equal to marginal cost for the beef output produced, where the marginal revenue is determined by existing prices received for the product that are less than those achievable when communication and feedback along the value chain is optimal. In situations where the processing sector considers chain feedback to be only an administrative cost and not a potential source of increased marginal revenue, decisions are often determined by the labour cost associated with preparing these outputs and the overheads necessary for that production: minimising both creates their margin. Processors therefore usually settle for providing the minimum amount of feedback required.

Those who control the grading system ultimately control the degree of potential product differentiation presented to the consumer and therefore the total "surplus" available for distribution throughout the value chain (Ferrier 2005). Industry implementation of MSA has focused on individual components of the grading system that are broad-based, targeting threshold components rather than fully separating ungraded, 3, 4 and 5 star product. Despite this limited implementation, MSA was estimated to have increased revenue by the equivalent of $0.32/kg hot standard carcass weight (HSCW) by Griffith et al. (2009) until 2007/08. This valuation was updated for the period up to 2010/11 to show an estimated average gain of $0.30/kg HSCW leading to increased revenue dissemination to the retailer, wholesaler and producer of $0.06, $0.11 and $0.13/kg HSCW respectively (Griffith and Thompson 2012). The proportion of extra revenue allocated to the producer was very similar to the 42% calculation within the Polkinghorne model (Polkinghorne 2006). Achieving 9% more revenue (Griffith et al. 2009) is a significant achievement that likely represents only the beginning of what can be achieved.

2.3.1 Consumer considerations

Consumers have a higher willingness to pay (WTP) when they have access to visual and taste attribute evaluations prior to purchase (Xue et al. 2010). The MSA method predicts the eating quality of individual beef cuts using critical control points in the production, processing and further processing sectors of the value chain (Thompson 2002, Polkinghorne et al. 2008b). MSA has identified a series of critical control points throughout the value chain that influence beef palatability (Ferguson et al. 1999, Polkinghorne et al. 1999, Thompson et al. 1999a,b, Watson et al. 2008b), This system can be linked to what consumers are willing to pay for various levels of eating quality (Lyford et al. 2010, Morales 2010).

In order to understand the further potential of the MSA methodology from a consumer value perspective, Lyford et al. (2010) studied the WTP of 6,718 consumers in Australia, the United States, Japan and Ireland from data collected during large-scale consumer taste tests and surveys. Their results highlighted the unfulfilled demand for 4 and 5 star product, where Australian consumers were prepared to pay 1.5 times more for 4 than for 3 star and 2.1 times more for 5 than for 3 star, while Japanese consumers were prepared to pay 1.7 and 2.9 times more than for 3 star, respectively. Most other countries were grouped with Australian consumers in their WTP.

Morales (2010) explored broader WTP considerations by investigating the demand characteristics for branded beef products. He identified the opportunity for developing brands where the value of a brand is to become an extrinsic quality cue that can help to predict eating and credence quality dimensions. (Morales 2010). The study concluded that there was significant potential to sell branded beef products throughout Australia, with the potential to increase the revenue obtained from consumers significantly. This will require better product presentation that effectively communicates the value consumers can expect before any premiums can be received. Improved product traceability, inventory management and information systems will be needed to ensure these expectations can be met. Hence, information throughout the value chain is crucial (Latvala and Kola 2000) and probably the most important contributor to maximising surplus in the beef value chain.

2.3.2 Production considerations

Everitt (1966, 278) highlighted the need for a more integrated approach to understanding the impacts of changes at one end of the value chain, such as animal growth rate, on changes at the other end of the chain, such as increased meat yield at the expense of marbling:

Fat is in least demand by consumers; it affects the yield and distribution of lean meat; and at the same time it is energetically most expensive to produce. There seems little point, therefore, in the continuation of traditional breeding policies. Rapid growth rate, coupled with high feed conversion efficiency, leading to maximum muscle production represent parameters of greatest importance.

Ongoing research has attempted to establish live animal assessments that reflect quality and yield traits. Perry et al. (1993) and Drennan et al. (2008) used live animal muscle and conformation scores to predict SMY, while Herring et al. (1994) matched live animal measures to carcass yield for selection of animals prior to slaughter, achieving the same accuracy as USDA yield grade. Hocquette et al. (2010) found that manipulating IMF independently from body fat depots using nutrition was more difficult to achieve than through genetic strategies. By finding live animal measures that accurately reflect quality and yield, management practices can be established to improve these traits.

While there is a significant lead-time to change management practices in preparing animals for sale, the genetic potential is already set and very difficult to change. It can take a minimum of two and usually three years to see changes start, then a further four to six years for any genetic changes to be established in a commercial herd. Given that the definition of breeding objectives sets the direction of breeding programs (Kinghorn 1998), it is important to have stability of purpose and clearly defined breeding objectives.

Genetic improvement is an important avenue for producers to improve efficiency and obtain more profitable animals. Genetic selection based on carcass traits is possible with the heritabilities reported by Reverter et al. (2003b). The estimated heritability values for RBY, IMF and marbling were 0.57, 0.38, 0.17 and 0.50, 0.39, 0.25 for temperate and tropical breeds, respectively. These moderate levels of heritability should facilitate genetic improvement if the beef industry provides feedback along the value chain. The feedback being provided cannot be cost-effective over the long term if no genetic progress is being made (Johnson 1996), A limitation of the current system is the lack of knowledge about genetic progress: without an integrated approach and clear long-term objective, no one really knows by what amount the value chain as a whole is improving or deteriorating.

2.3.3 Processing considerations

The relationship between some carcass components and their distribution over the carcass is well understood but not easily standardised. Each processing facility varies slightly from another due to the variations of skill and discipline of individuals boning and trimming the primals on the production line. Primals contain various combinations of the three primary tissues – muscle, fat and bone – according to the boning priorities of individual facilities and can range in value from $1/kg to $21/kg. With such large variations in value, it is important to specify the cutting lines and level of trim associated with each primal. To communicate these combinations more effectively, AUS-MEAT (1998) and the North American Meat Processors (NAMP 1997) have developed detailed templates for standardising primal cutting specifications. More recently, AUS-MEAT has collaborated with the United Nations to produce a handbook on carcass and cuts definitions to be used as a voluntary standard for international trade (UNECE 2004).

Generally, processors focus on how to maximise the amount of fat left on the primal to increase weight sold and therefore total revenue. The price per kilogram achieved is moderated by customers' WTP for excess fat. Effectively, selling fat at primal prices will always generate a higher return than selling fat to be incorporated into mince or rendered. This principle is also true of bone being sold as bone-in primals rather than bone, although the market is aware of their problematic nature. Bone-in primals generally have a shorter shelf-life as well as a higher tendency to burst vacuum packaging bags causing 100% product loss and are therefore priced accordingly. These strategies aim to improve the return of the fat and bone tissue, but they can ultimately detract from the return associated with muscle due to the "risk" discount applied by customers.

On the other hand, processors would like to receive higher-yielding animals. Conroy et al. (2010) described multiple regression equations to predict carcass proportions of meat, fat and bone using European carcass classification scores for conformation, fatness and hindquarter composition. Johnson (1996) advocated the carcass beef measure of yield outlined by Charles (1977) as a basis for trading animals. This is because it effectively combines the commercial acceptability associated with SBY while having the improved accuracy of estimated lean meat yield to be useful for genetic improvement. The other major benefit is that it could be estimated from the use of existing carcass measurements of carcass weight and subcutaneous fat at the P8, FT10 or FT12 site. Communicating any meat yield measures independent of quality is likely to encourage producers and processors to select for higher yielding animals with no consideration of any quality aspects or other equally important traits associated with calving ease and feed conversion. To be sustainable at the production end of the value chain, complete information needs to be translated back to the live animal to facilitate more effective decision making in selection.

Processors are also mindful of purchasing animals on a liveweight basis because it requires estimating the dressing percentage of the animal. In this context, dressing percentage is important to carcass value. Animals that achieve a higher carcass weight relative to liveweight will be cheaper than those that are lighter carcasses for the same liveweight. However, unless this higher carcass weight is generated by higher SMY (Butterfield 1966), it is of no value to the processor. Higher dressing percentage can be caused by higher fat yield, although this advantage can be offset by higher labour costs to trim the excess fat from the primal (Berg and Butterfield 1976). High dressing percentage effectively selects animals with relatively small organs that may also negatively affect production efficiency.

According to Gardner et al. (1997), the evaluation of meat yield ideally needs to be achieved without impeding product flow through the abattoir. But this product flow should be tested within the context of value chain optimisation and the potential commercial implications of tracing the primal to the point of consumption for bio-security, food safety and, most importantly, consumer eating satisfaction.

2.3.4 Traceability considerations

Logically, deboning the carcass, weighing the components produced, recording carcass measures and reporting the information generated as feedback to producers would provide the best communication. In reality, individual companies set management priorities that determine product specifications and available infrastructure that need to be managed within the ever-present constraint of time. As a result, carcass traceability is usually limited to a production day or, at best, a production shift. Also, the processes employed within a deboning operation will determine the traceability of carcass components. The vast majority of boning facilities around the world are based on a chain system that moves carcasses from one station to the next, handling discrete components of the carcass at each station. The product is then trimmed and transferred to a centralised packing area via tubs or transfer conveyors. In these instances, collecting information on individual carcass components has largely been deemed to be too expensive. There has been some uptake of DNA testing and bar-coded or radio-frequency identification gambrels to assist in traceability of carcasses (Finlayson 2012) but rarely any further on toward primals[2].

Without individual primal traceability, processors have used “national boning groups” to identify quality grades for primal cuts. The standardised boning group approach used across Australia is a significant impediment to the full implementation of MSA for three main reasons:

1. This approach consolidates product, usually with a range of eating qualities above a pre-determined level. The result is that better quality product is given the same grade as the lowest common denominator to minimise the risk of failure.
2. The boning group approach limits the ability of processors to harvest cuts from their production. To utilise the full potential of MSA, processors need to be able to access particular cuts at defined quality levels that are set by the customers, not predetermined by external operators. The current application of MSA boning groups is not sufficiently dynamic to work effectively with boning room production schedules and harvest cuts in response to customer demand.
3. The boning group approach limits the flexibility required to manage inventory and market product effectively when circumstances change, such as customers misinterpreting specifications or changing their mind. There are significant logistical challenges such as stock codes, labelling and inventory management. Nevertheless, overcoming these challenges will clear the bottleneck limiting the full implementation of MSA throughout the value chain.

The expenses incurred are twofold, through the provision of processing facility infrastructure (both structural assets and information systems) and the labour required to achieve the traceability. Hence, the focus by industry has been on finding an accurate and rapid dissection technique (Johnson and Charles 1981) that is cost effective. By focusing on higher throughput, managers significantly reduce the unit cost to re-coup the initial investment and cover on-going maintenance costs. In a high volume, low margin environment, incremental change can be achieved but it is harder to change fundamental paradigms of production to achieve traceability.

2.3.5 Whole value chain considerations

Creating awareness of the interrelationships amongst the various stages of the beef value chain should, in theory, enable modelling from other manufacturing and production industries to be applied to the beef value chain. In the manufacturing industry, Gong (2008)

[2] There is some anecdotal evidence that two major processors have achieved traceability to the primal level, but this has not yet been validated.

found that “The bottleneck factor decides the level of system product mix flexibility.” In the beef industry, the “bottleneck factor” is undoubtedly the traceability from the carcass to the packaged primal. This traceability is fundamental to the ability of MSA to predict the various eating experiences possible at the consumer level. Without this traceability and communication established, the entity preparing the product for the final consumer cannot be aware of the predicted eating outcome possibilities and therefore adjust preparation accordingly.

The global nature of the beef industry renders markets dynamic, subject to fluctuating demand and currency volatility. Businesses at all levels need to be flexible and able to respond to these ever-changing circumstances. Understanding these factors, and incorporating consumer demand and producer supply considerations, gives an opportunity to establish effective modelling tools. These models can provide useful insights into mitigating risks and highlighting opportunities.

Chopra and Meindl (2012, 19) defined the competitive strategy of a firm as “relative to its competitors, the set of customer needs that it seeks to satisfy through its products and services”. A value chain[3] strategy – how to structure the value chain for the medium to long term – is derived from the competitive strategy and is based on the creation of a suitable strategic fit and strategic scope for a particular product. According to Chopra and Meindl (2012), the appropriate scope is an intercompany one, where the view is to maximise chain surplus (profitability) by all firms in the chain working together and sharing information.

Three steps are followed when establishing the zone of strategic fit for a value chain: understanding the customer and value chain uncertainty; understanding the value chain capabilities; and achieving a strategic fit (Chopra and Meindl 2012). In the case of the beef value chain, two decisions need to be made that correspond to the first two steps and lead to the third step: deciding on the degree to which consumer demand for the product in the chain is certain or uncertain; and deciding if a value chain is able to respond to a wide range of quantities demanded, meet short lead times, handle a variety of products, build innovative products, meet a high service level and handle supply uncertainty (Chopra and Meindl 2012), The third step is to decide whether it should be a responsive value chain or an efficient value chain (one that operates at the lowest possible cost) (Mounter et al. 2015).

The beef value chain has a high degree of implied uncertainty, defined by Chopra and Meindl (2012, 23) as the uncertainty of consumer demand for a product “for only the portion of demand that the supply chain plans to satisfy based on the attributes the customer desires”. In particular, knowledge is lacking of meat quality across all cuts of meat and what qualities consumers desire in each cut of beef. Second, participants in the value chain need to be highly responsive to changing consumer tastes and preferences, which requires a high level of knowledge about consumer preferences to be transmitted to all stages in the chain between producers and consumers. In achieving a strategic fit, then, the aim of a firm is “to target high responsiveness for a supply chain facing high implied uncertainty” (Chopra and Meindl 2012, 27).

Chopra and Meindl (2012) stipulated that the role of each stage in the chain should be aligned to support the value chain strategy through the use of sets of three logistical drivers (facilities, inventory and transportation) and three cross-functional drivers (information, sourcing and pricing). While all six drivers are relevant in influencing the performance of the beef value chain, the information driver is the one of most relevance to this context. Chopra and Meindl (2012) identified several components of information decisions that are prominent in a value chain. One of these components, information technologies, is particularly valuable in the beef value chain and offers great scope to increase chain profitability by enabling a closer match of beef products to the preferences of consumers.

[3]Chopra and Meindl (2012) use the term supply chain while we prefer the more recent term of value chain. We substitute the latter for the former when we are discussing material taken from their book.

To be capable of creating a profitable responsive value chain, chain participants need timely and complex information. These enabling technologies can make producers and other chain participants more responsive to changing consumer preferences and thereby improve overall chain surplus (profitability).

The opportunity is to integrate information and clarify the importance of individual eating quality and carcass yield traits. The traditional measure of quality has largely been attributed to the measure of IMF, or marbling. It has been assumed that increased IMF positively influences flavour, juiciness and tenderness (Hocquette et al. 2010). As noted previously, MSA research has highlighted the interconnectivity of pre- and post-slaughter treatments and the traditional measurements of marbling, IMF and ossification on consumer palatability scores (Ferguson et al. 1999, Polkinghorne et al. 1999, Thompson et al. 1999a, Thompson 2002, Johnston et al. 2003a,b, Reverter et al. 2003a,b, Polkinghorne 2006, Polkinghorne et al. 2008b).

These results are supported by the findings of Berg and Butterfield (1976) that excess fat is detrimental to SMY% and not enough fat is detrimental to eating quality. By combining the influence of eating quality and yield traits into the decision making process, customers' needs can be met more effectively while maximising profitability for the value chain participants. "While looking to manipulate growth in the quest for greater efficiency, we need to be mindful of the beef characteristics that make it demanded by consumers so that these are always retained." (Berg and Butterfield 1976, ix). Having the priorities of all value chain participants aligned with the consumer is important for the long-term sustainability of the beef industry.

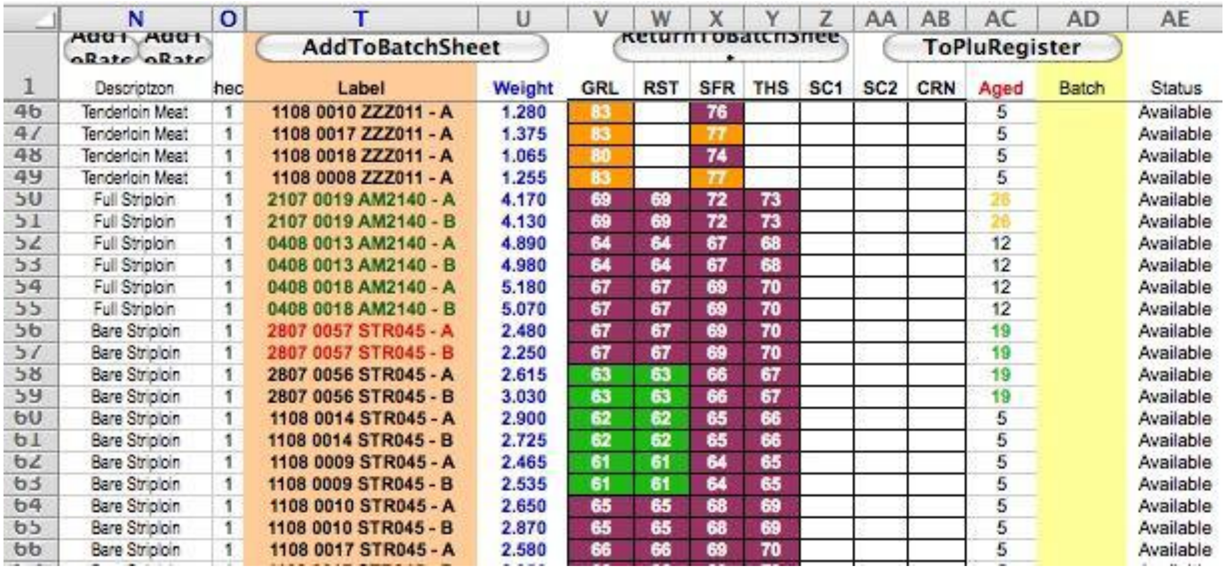
What is often overlooked in discussions about MSA grading is the fact that it should remain a dynamic tool. As better information and new understanding is proven, it should be incorporated into this modelling (Watson et al. 2008b), thereby more closely aligning predictions with consumer expectations. There has been little modelling done on the financial aspects of these critical points, making it difficult to quantify their impact on the profitability of participants in the beef value chain. Having such a process would provide new understanding of the chain's integrated nature.

2.4 Processing case study: Polkinghorne's value chain in Australia

The Polkinghorne's value chain was built on full traceability from producer to consumer (Polkinghorne 2006, Polkinghorne et al. 2008a), requiring a purpose-built database that colour-coded the scores to reflect one of four MSA grades for individual portions for each cooking method (Figure 1). Red font on a white background indicated the portion scored <47.5 and was UG (ungraded), All graded product was distinctly recognisable with a white font on several backgrounds within the records cell. A green background indicated the portion scored ≥47.5 but <63.5 and was 3 star eating quality for each of the six cooking methods. A purple background indicated the portion scored ≥63.5 but <76.5 and was deemed 4 star, while a gold background indicated the portion scored ≥76.5 and was deemed 5 star. This database of primal information was essential to record processing yields accurately and to maintain product traceability as it was transformed throughout the value chain.

To limit the risk of supplying a poor eating experience to the consumer, a group of muscles with differing eating qualities, such as the rump primal, were rated according to one of the lower eating qualities of its components (Polkinghorne et al. 2008a). This component is signified as the "Deem Cut", i.e. deemed most effectively to represent the primal to achieve this risk-mitigation objective.

Figure 1: Inventory database screen snapshot showing primal description, check field, label information, weight of primal, seven cooking method (GRL – grill; RST – roast; SFR – stir-fry; THS – thin-sliced; SC1 – slow cook for one hour; SC2 – slow cook for two hours; CRN – corned), Aged: days aged since kill date; Batch: batch assigned when taken from inventory for further processing and invoiced; Status: eating quality scores calculated daily using individual cut ageing coefficients



	N	O	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
			AddToBatchSheet								ToPluRegister			
1	Descriptzon	hec	Label	Weight	GRL	RST	SFR	THS	SC1	SC2	CRN	Aged	Batch	Status
46	Tenderloin Meat	1	1108 0010 ZZZ011 - A	1.280	83		76					5		Available
47	Tenderloin Meat	1	1108 0017 ZZZ011 - A	1.375	83		77					5		Available
48	Tenderloin Meat	1	1108 0018 ZZZ011 - A	1.065	80		74					5		Available
49	Tenderloin Meat	1	1108 0008 ZZZ011 - A	1.255	83		77					5		Available
50	Full Striploin	1	2107 0019 AM2140 - A	4.170	69	69	72	73				26		Available
51	Full Striploin	1	2107 0019 AM2140 - B	4.130	69	69	72	73				26		Available
52	Full Striploin	1	0408 0013 AM2140 - A	4.890	64	64	67	68				12		Available
53	Full Striploin	1	0408 0013 AM2140 - B	4.980	64	64	67	68				12		Available
54	Full Striploin	1	0408 0018 AM2140 - A	5.180	67	67	69	70				12		Available
55	Full Striploin	1	0408 0018 AM2140 - B	5.070	67	67	69	70				12		Available
56	Bare Striploin	1	2807 0057 STR045 - A	2.480	67	67	69	70				19		Available
57	Bare Striploin	1	2807 0057 STR045 - B	2.250	67	67	69	70				19		Available
58	Bare Striploin	1	2807 0056 STR045 - A	2.615	63	63	66	67				19		Available
59	Bare Striploin	1	2807 0056 STR045 - B	3.030	63	63	66	67				19		Available
60	Bare Striploin	1	1108 0014 STR045 - A	2.900	62	62	65	66				5		Available
61	Bare Striploin	1	1108 0014 STR045 - B	2.725	62	62	65	66				5		Available
62	Bare Striploin	1	1108 0009 STR045 - A	2.465	61	61	64	65				5		Available
63	Bare Striploin	1	1108 0009 STR045 - B	2.535	61	61	64	65				5		Available
64	Bare Striploin	1	1108 0010 STR045 - A	2.650	65	65	68	69				5		Available
65	Bare Striploin	1	1108 0010 STR045 - B	2.870	65	65	68	69				5		Available
66	Bare Striploin	1	1108 0017 STR045 - A	2.580	66	66	69	70				5		Available

Inventory utilisation and value

Consistent with the base principle of traceability, all the products generated from further processing were recorded. Furthermore, the yield of each product generated was also recorded as well as the price received for each product. These products were marketed direct to company-owned retail stores or wholesaled to external businesses. An example of the decision process followed is described in the following quotation:

> For example, the *M. rectus femoris* could be fabricated and sold primarily as either steaks or a roast. Steak preparation typically yielded 78% of the muscle as steaks with 5% sausage trim, 12% fat and a 4% cutting loss. In comparison, an 89% roast yield was obtained with 7% sausage trim, 3% fat and 1% cutting loss. If the primary objective was to produce stir-fry or casserole cubes, further yield mixes would apply. The return from the muscle was dependent on the combination of the weight of the primary and secondary products and on their respective prices. The eating quality of this muscle is affected significantly by cooking method (MSA model estimates) with typical results being a 4 star roast but only 3 star steak. As retail pricing was based on grade, the overall return for *M. rectus femoris* from an average carcass was \$31.89 when prepared as steak in contrast to \$42.25 when prepared as roasts. Consequently, sale as a roast was planned wherever possible to optimise return. A similar decision process was followed for other carcass portions. (Polkinghorne et al. 2008a, 1454)

The traceability in the processing stages facilitated communication of information throughout the value chain. Because of this traceability and record keeping, a value for each primal could be established. The "live" inventory value, yield and eating quality information created the opportunity to optimise the return of primals by choosing how they would be processed on any given day. This traceability facilitated the flexibility necessary for the business to respond to changing consumer demands requiring alternative inventory utilisation, isolating quality assurance breaches and, most importantly, translating value between each participant of the chain.

<u>Supply and pricing to the retail store</u>

Demand for retail products was driven by customer sales at the retail store. The inventory of primal cuts was then further processed into the required retail-ready items or sold into the wholesale market. Cuts processed into retail-ready items were done in batches and full yield records were obtained. This information included primary and secondary items produced from each primal batch being processed, as well as any associated trims and waste. The cutting loss or gain was calculated as the deduction of all other quantities from that of the source material (Polkinghorne et al. 2008a).

By combining the retail price paid by consumers and the processing yields recorded at each step of the process, a unique pricing methodology was established. Polkinghorne (2006) assessed the market supply and demand forces to establish 65% as a reasonable and sustainable price point, characterised in Figure 2. That is, the wholesale primal prices used were calculated as 65% of the retail value achieved for the cut depending on the quality grade achieved, namely UG, 3, 4 or 5 stars.

The value calculation was a function of retail price by the quantity of retail-ready product, trim, fat and bone generated during the preparation of the item. A number of new retail-ready products were developed. Wherever possible, the first marketing priority was to sell through the company-owned retail outlet. If this was not possible, wholesaling to other MSA outlets was pursued before using the broader wholesale market.

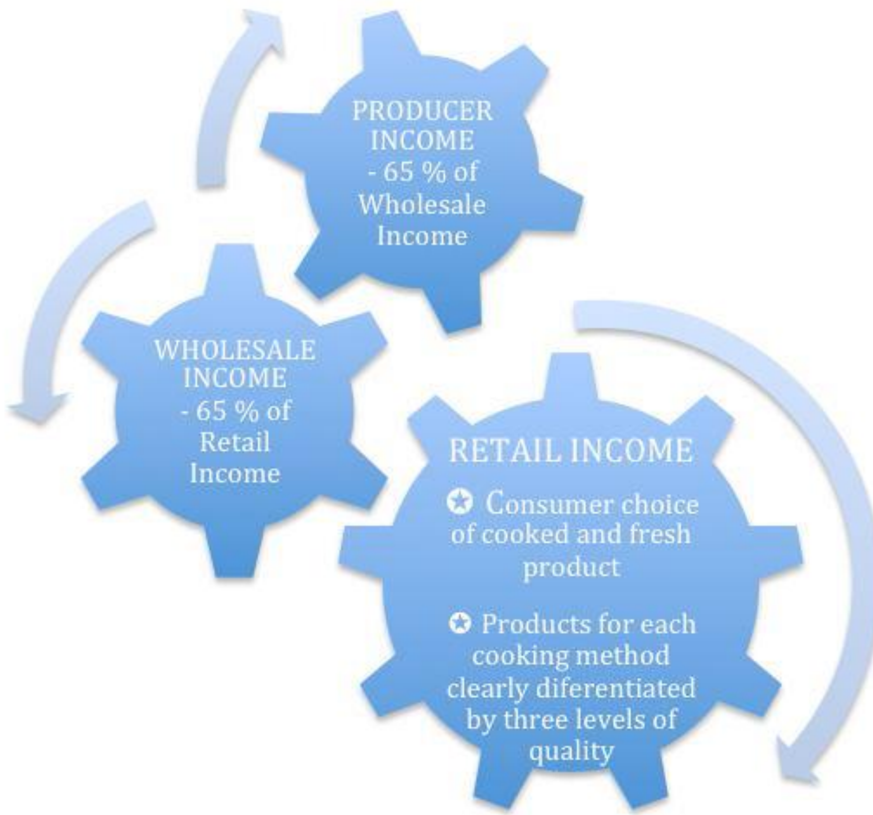
A value for each primal at each of the four quality grades could be determined over a defined period of time. Depending on cut-utilisation strategies employed for different quality grades, primal returns could vary significantly. The value for each primal was calculated individually for each of the four quality grades. The prices paid for each 3 star primal ranged from $2.94 per kilogram for *M. gastrocnemius* to $17.03 per kilogram for *M. psoas major*. Carcass value was determined by summing the total value of the relevant component primals, trim, fat and bone that each animal was boned into. This method provided a direct market signal from retail consumers throughout the value chain because of the custom-built traceability and feedback systems.

This case study represents a new value chain paradigm. The methodology employed provides a framework to deliver a consumer-focused product that is highly responsive to changing consumer demands, tailored to suit their needs. This whole value chain approach also addresses traceability concerns to guarantee food safety while simultaneously communicating accurate eating quality and carcass yield through value-based payments. The alignment of participants throughout the value chain means consumer feedback could be used to facilitate genetic improvement, thereby closing the feedback information loop.

2.5 Effective beef value chains

Value translation throughout any value chain should communicate the contribution of individual components toward achieving a desired outcome, where the desired outcome has been outlined and requested by the ultimate consumer. By “beginning with the end in mind” (Covey 1989), there is an opportunity to create an alignment of individual goals and vastly improve the effectiveness of the value chain. This was evident when the two original objectives for implementing a grading and classification system for beef carcasses were outlined as: first, to develop uniform grading standards that could report market pricing; and second, to provide feedback to suppliers about market requirements (Harris et al. 1988). While the original objectives were noble, they have proved elusive over the past 100+ years since Herbert Mumford first proposed them in a series of bulletins entitled *Market Classes and Grades of Cattle with Suggestions for Interpreting Market Quotations* in the early 1900s (cited by Harris et al. 1988).

Figure 2: Polkinghorne's value chain characterisation



Typically, institutions established voluntarily or by regulation tend to run their course and slowly become less relevant. Australia's implementation of the AUS-MEAT language in 1987 for carcass description was to accurately describe gender, dentition (as a measure of age) and carcass weight because the definition of "carcass quality" varied depending upon the customer and destination (Polkinghorne and Thompson 2010). The USDA quality grades were never intended to provide point estimates for expected beef palatability, according to Smith et al. (2008). In both Australia and the United States, implementing effective communication throughout the value chain has been subject to a "similar history of local, state and national political interference" (AHDB 2008). The United Kingdom experience reflects that of Europe as a whole, suffering from a lack of transparency, poor product description between value chain participants and feedback unduly influenced by a focus on subsidies and market support rather than consumer requirements (AHDB 2008). None of these existing structures adequately provides the feedback necessary for increasing compliance or productivity.

The two primary objectives of beef carcass grading systems are to estimate a measure of carcass yield and determine the eating quality of the meat (Indurain et al. 2009). Given the value chain as a whole is a system, and the value chain in its parts are the components (Gow et al. 2003), it follows that there needs to be understanding "about the impact of selection for any given trait on other economically important traits such as carcass yield, quality, feed conversion or fertility so that there are no unfavourable correlated responses to selection" (Clarke et al. 2009b, 940). Unless we understand these interactions, we cannot incorporate the outcomes into daily management decisions.

The calls by Pethick et al. (2010) for a new wave of structured research should be vigorously supported. However, it should also be recognised that this is not a new approach; rather, it re-ignites previous calls for a more coordinated research focus outlined by Polkinghorne (2006, 182) that:

> ……concerted application of meat science research findings would assist in delivering consistent quality products to the consumer. These must be augmented by industry procedures, which can apply the science in a working commercial environment and achieve balanced clearance of all carcass components. The commercial incentive to adopt such changes must come from the adoption of systems, which relay accurate information and directly link price to consumer value at all trading points.

This approach was also supported by Everitt (1966, 267) when he quoted Friedlander (1964): “The first important factor (in meat production and research) is the necessity of breaking down the barriers previously existing between primary production, processing and marketing so that one can have a direct line of communication.”

Studies of isolated components of this integrated system is probably one further reason for our lack of progress in achieving accurate appraisal of quality at each processing point along the chain from dinner plate to the live animal (Butler 1960). Concern about this lack of progress is as relevant today as it was 50 years ago except that now the industry can access the MSA methodology representing the best existing total quality management approach for improving beef quality and palatability (Smith et al. 2008). The challenge is to implement this system effectively and meet consumer demand by actively redefining the linkages between the value chain participants.

3. Opportunities

There are three distinct opportunities to change the way participants interact within the beef value chain that should deliver a more valuable array of beef products.

3.1 Expanding and evolving the MSA methodology

There is an opportunity to expand and evolve the MSA methodology. It is important to remain focused on the consumer implications of any action by analysing the inter-related effects of treatments performed in one section of the value chain on those participants upstream or downstream. The PACCP methodology developed by MSA (Ferguson et al. 1999, Polkinghorne et al. 1999, Thompson et al. 1999a,b) was the first methodology to address the beef value chain with this approach.

The industry must avoid isolating this body of knowledge accumulated within the MSA methodology. It cannot confine it to a “box”, believing the job is done and the knowledge is complete. History has taught us that knowledge evolves and gains clarity over time. Knowledge should only be truly accepted after being thoroughly tested. The development of MSA is an appropriate example of an evolving system that started grading whole carcasses as one quality grade to now grading 39 individual cuts by six different cooking methods; from grading all cattle breeds as equals to currently assigning fixed effects related to *Bos indicus* content; and from not identifying animal treatments to recording whether or not they are treated with hormonal growth promotants. It is important to maintain a questioning mentality that continually tests and re-tests the underlying assumptions fundamental to the workings of the model: this is the essence of the entire system. Should subsequent studies disprove the current assumptions and coefficient values, the model itself should be updated and modified accordingly. The ability to manage this process effectively will determine whether or not it can remain dynamic, evolve with our understanding and thereby maintain its relevance.

The crucial role of information in applying MSA in the beef value chain has been highlighted above. Disseminating this information will likely require further software and systems development. This software development could pursue bio-economic production modelling and assist resource allocation decision-making programs. It could also be useful in value chain modelling for biological efficiency or herd modelling programs or risk management mitigation. It will also be required to manage the logistical challenges associated with tracking multiple primals in cartons, on pallets and throughout a distribution network.

3.2 Enhancing the traceability of retail product to the point of origin

Traceability of retail product to the point of origin achieves the two important functions of food safety and marketing flexibility. Food safety is of paramount importance to the consumer and the entire beef value chain is facing increased regulatory demands after the bovine spongiform encephalopathy outbreaks in the United Kingdom and Japan, foot and mouth disease in Argentina and other South American countries, and *E. coli* issues in ground beef in the United States. With a systematic approach to traceability established, problematic inventory can be rapidly and accurately isolated and quarantined from the food supply channels. This should enable continued market access, retention of consumer confidence and minimise the imposition of any further regulation.

Marketing flexibility is obtained by maintaining the eating quality information of primals up to the final point of retail sale. To facilitate the passage of this information, systems are required that maintain product traceability to translate information up to the point of sale so that decisions on product presentation at the retail level can be made with confidence. The majority of people presenting beef to the ultimate consumer are often confronted with limited information, despite it being of paramount importance at the point of final sale. For example, the round primal (also known as knuckle) is often prepared as a barely acceptable grilling steak after passing through a tenderiser, when it could alternatively be presented as an above-average roast, cut into stir-fry portions or diced for use in a casserole. The bottleneck is that insufficient information is available accurately to determine which primal is appropriate for each presentation. By addressing this communication breakdown, there is an opportunity to increase revenue, or at the very least satisfy the consumer need more effectively, thereby increasing the likelihood of a repeat purchase. Essentially, resolving these process logistics will unlock the full potential of MSA.

Traceability of quality can improve processing efficiency. Traditionally, the Australian domestic market has been constrained to use smaller carcass weights that are more expensive to process. Heavier carcass weights could be utilised to supply domestic consumers if they are selected for equivalent meat quality levels. McIntyre in Johnson (1994) referred to supermarket carcass weight specifications as being driven by consumer preferences. The author contended that the carcass weight specification represents a pseudo indicator of portion size due to the influence of carcass weight on primal size. An alternative is the further dissection of primals into their smaller sub-components. Not only does this address the issue of primal size, it has the added benefit of providing a product that eats more uniformly throughout the resultant primal (Polkinghorne et al. 2008a).

Another application could be to create a live, fully tailored, predictive sorting system that provides real-time information on the kill floor allowing carcasses to be organised into newly defined boning groups based on individual customer needs and just-in-time inventory principles (McGilchrist et al. 2012). Such a model could maximise the overall net revenue through the value chain as outlined by Gheidar Kheljania et al. (2009). This requires planning and coordination among all entities in the chain if it is to be effective (Gheidar Kheljania et al. 2009).

3.3 Providing effective feedback

Closing the information loop by improving the systems providing product traceability can provide effective feedback to all value chain participants. By incorporating more detailed eating quality and carcass yield information with traceability, feedback systems to producers would be vastly improved as suppliers modify their management practices to calibrate the level of carcass fatness and reduce their input costs. Processors may also recognise the interdependence of the beef value chain and actively engage with producers to provide more effective feedback about eating quality and saleable meat yield.

The logical progression would enable the extended development of integrated modelling between live animal growth and carcass dissection as demonstrated by Slack-Smith (2009), as well as provide valuable genetic feedback. Such developments could generate significantly improved efficiencies in the beef industry at levels normally associated with the dairy and pork industries. Given that individual cuts of reasonable value could be identified and harvested the relative value of cull females may also increase in the commercial market place by the removal of current discounts imposed on suppliers.

The development of the MSA Index is a positive step to provide a better benchmarking that can be used by producers to use management and genetic to improve eating quality (Thompson et al. 2012). The MSA index summarises the impact of all animal and carcass input traits used by the MSA model and will allow producers to evaluate changes in their business, and ultimately drive a faster rate of improvement in eating quality.

The importance of carcass meat yield in its various forms as a measure of carcass performance has been investigated by many previous studies such as Murphy et al. (1960), Crouse et al. (1975), Charles (1977), Johnson and Charles (1981), Lunt et al. (1985), Johnson and Ball (1989), Johnson (1994) and Conroy et al. (2010). The important point to note is the lack of a yield measurement to provide commercial information. The limitation to providing this has been the capital infrastructure and process flow necessary to collect the information, and the labour required to do it. Nevertheless, selecting for carcass yield in isolation of quality traits will likely be detrimental to functional aspects of beef production and the long-term ability of the value chain to respond to changing consumer preferences.

The Australian dairy industry for example has adopted a component payment system for volume, milk fat and milk solids. Annual production per cow has increased by 91% over the past 30 years from 2,848 litres in 1979–80 to 5,445 litres in 2009–10 (Anon 2011). A Canadian pork cutout trial in 1992 (Anon 1992) highlighted a 6–7% improvement in lean meat yield compared with an earlier trial in 1978 and attributed 50% to genetic improvement. Also, the average Canadian hog carcass increased from 79kg in 1990 to 94kg in 2010 (Anon 2010). Such changes significantly decrease the fixed processing costs per litre of milk or per kilogram of pork produced, respectively. These results demonstrate the significant improvement that can be made with better feedback throughout the value chain, thereby increasing total revenue, through better asset and labour utilisation within these value chains.

In order to capture these gains in the ongoing search for improved processes and efficiency, it is likely the beef industry will need to look externally at how this has been achieved in other industries. Hines et al. (2006) describes a combined Target-Kaizen costing approach applicable to lean manufacturing-enabled businesses. The target price represents the maximum allowable at the start of the product lifecycle while the Kaizen costing is the price point toward the end of the product life cycle, usually expressed as a percentage. This price change can then represent the change in the cost of production over time, leading to the application of lean manufacturing principles. This combined approach has been taken from the Japanese automotive industry where it plays a central part in the achievement of the quality, cost and delivery goals stipulated in customer specifications (Hines et al. 2006). It is but one approach requiring further investigation for its appropriateness to the beef value chain.

When the linkages between value chain participants are effective, confidence builds and longer-term decisions are more likely to be made. The more defined or predicted an outcome is, the better is the chance of managing the influence it has. MSA provides an avenue to understand and segment customer specifications in terms of quality that, when combined with traceability, can be expanded to include cost and delivery goals. Collected correctly, this information can be invaluable to manage product margins and more effectively set prices that reflect consumer demand. Providing more effective producer feedback would also assist producers to make decisions about alternative breeding and management strategies.

By overlaying such information systems on top of the exiting PACCP pathway used as the basis for the development of the MSA technology (Ferguson et al. 1999), there is an opportunity to create economic weights to the MSA grading model inputs, thereby creating a complementary financial model. That is the next step on the way to developing an integrated value-based marketing system for beef in Australia that would more effectively communicate consumer value to participants at all levels throughout the value chain.

4. Summary and Conclusion

The beef value chain consists of many components that together form an integrated system. Until now, these components have been studied in isolation, thereby limiting progress. Progress has been further hampered because the feedback throughout the chain does little to communicate value. Without quality differentiation, consumers are constrained in their capacity to express choice. It therefore follows that market premiums cannot be determined and consumer demand signals cannot be accurately communicated until quality differentiation is properly addressed throughout the value chain.

The development of the MSA grading model represents the best existing total quality management approach for improving beef quality and palatability because of its ability to predict consumer satisfaction with a cooked meal. But it goes only part of the way to address quality differentiation in its present format.

Communicating the quality of the product to the consumer, so that they can provide demand signals to the value chain in a way that translates back through each participant of the value chain, aligns everyone toward a common goal. Effective pricing methodologies need to be implemented to reflect carcass value more accurately. These results need to be incorporated as a component of a larger framework, rather than being considered in isolation. The ultimate application of these results would be as part of wider, value-based marketing system that incorporates the whole beef value chain.

Providing effective feedback requires effective information systems, which are a key performance driver in the value chain due to the direct influence of information on all other drivers. Improving information systems inevitably requires improved software and integration of independent systems to provide decision-making tools.

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