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REVIEW

Update of Meat Standards Australia and the cuts based grading scheme for beef and sheepmeat



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Abstract

Changing markets and evolving consumer demand present new challenges for the beef and sheep industries. In response, the industry has been investing in innovations to deliver new products and management systems to consumers. One such innovation is the Meat Standards Australia (MSA) system. This system is a Total Quality Management System, aimed at delivering an eating quality guarantee to consumers, and through this adding value to the entire supply chain. At present, it is well developed for beef and still evolving for sheepmeat. MSA has identified Critical Control Points (CCPs) in the production, pre-slaughter, processing and value-adding aspects of the supply chain that impact on consumer palatability through the large-scale taste testing of meat by untrained consumers. These CCPs are used as either (1) mandatory criteria determining eligibility for grading, and (2) inputs in a model predicting the palatability of individual combinations of muscle and different cooking methods. Through the prediction of palatability, MSA increases consumer satisfaction and is used to provide assurance for branded products and new marketing innovations in Australia and internationally. This has added significant value to the Australian beef industry, with several retail examples demonstrating consumer willingness to pay more for premium quality beef and sheepmeat products based on the MSA grading scores. This price differential at retail allows the value of the carcass to be calculated based on the eating quality as well as the volume produced, thereby delivering a financial reward for farmers producing high quality carcasses. The continuous quality scale of MSA allows producers to realise the financial gain of incremental improvements in quality, as well as the precise economic weights associated with traits such as marbling, ossification score, or breed. The use of MSA in this fashion has underpinned a new and innovative supply chain where the pricing is transparent and allows producers to make informed decisions to modify both quality and yield traits. To date, the MSA system for beef has proved to be effective in predicting beef palatability not only in Australia but also in many other countries (France, Poland, Ireland, Northern Ireland, Japan, South Korea, New-Zealand, the USA and South Africa). In Europe, results of the ProSafeBeef and ProOptiBeef projects as well as other national projects demonstrate the potential to develop an MSA-like international grading system for the supply chain in the EU, despite the

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diverse cultures and complex beef production systems within the member states. International testing in lamb has only just begun and preliminary results are discussed here.

Keywords: eating quality, consumer, beef, sheep, Meat Standards Australia, international, cut

1. Introduction

Consumers have difficulty selecting red meat of a consistent or reliable eating quality and this is seen as a major factor in the global decline in beef (Morgan *et al.* 1991; Henschion *et al.* 2014) and sheepmeat consumption in developed countries (Russell *et al.* 2005; Pethick *et al.* 2011). As the eating quality of beef and lamb is experienced by the consumer after purchase, it heavily influences a consumer's intent to re-purchase the product (repeat purchase intent) (Grunert *et al.* 2004; Pethick *et al.* 2006), one of the biggest drivers of profitability for an industry. Within the red meat industry, there are many different grading systems designed to add some consistency and transparency to red meat supply chains. For beef, these systems are intended to rank individual carcasses into a number of grades. Most are designed to capture carcass shape and yield, although some claim to rank carcasses on the basis of quality. These yield and quality grades are usually determined by a variety of objective and subjective measurements such as fat depth, meat colour, marble, carcass fat and conformation scores, and texture scores (Polkinghorne and Thompson 2010). However, when related to sensory scores, these grades poorly discriminate on eating quality, generally accounting for less than 15% of the variance in consumer taste panel scores (Bonny *et al.* 2016b; reviewed by Polkinghorne and Thompson 2010).

Meat Standards Australia (MSA) represents a new approach to grading carcasses, differing markedly from other systems currently employed around the world. Firstly, it independently grades each cut (MSA for beef) rather than applying a common grade to the entire carcass. Muscle type, rather than breed, age or other carcass factors, explain most of the variability of beef eating quality (Jurie *et al.* 2007). Secondly, the definition of quality is based on responses of many thousands of untrained consumers, rather than trained consumers or instrumental measures. Since its inception in 1997, over 700 000 beef samples have been tested using more than 100 000 consumers, and testing 9 000 sheepmeat cuts involving 15 000 consumers have been evaluated (Meat and Livestock Australia 2017). Previous research had clearly shown that beef eating quality was a reflection of all the events that have occurred up until consumption, including when the steak was cooked.

Failure of only one link in this chain can increase the risk of a poor-eating experience for the consumer. Therefore, the MSA system uses a Total Quality Management System approach to grading, incorporating both pre- and post-slaughter information coupled with carcass measurements taken in the chiller (such as *post-mortem* stress, pH and temperature decline) (Polkinghorne *et al.* 2015).

This paper briefly describes the current state and future directions of MSA for both beef and sheepmeat. It describes the input parameters used to predict palatability using the MSA beef model, followed by a brief description of the Critical Control Points (CCPs) for palatability and how this is integrated into the MSA prediction model. Information will be provided describing the recent extension of the system into grading sheepmeat. Finally, research demonstrating that such a system is also applicable to international consumers and supply chains is presented.

2. Measurement of beef palatability by MSA

A decline in beef consumption was evident from the 1970's onwards, and was a significant concern for the Australian beef industry. Since 1990, funding and research priorities have focused on supplying a more consistent product and accurately describing palatability for the consumer (CIE 1996). This was termed MSA and the program was placed in the care of the newly formed Meat and Livestock Australia (MLA) organisation, which is responsible for marketing, research and development for Australia's red meat and livestock industry. First, the decision was made to move away from trained panellists and instrument measures of quality, and to use sensory results from consumer taste panels as the ultimate determinant of eating quality. To evaluate meat samples, untrained consumers scored samples on 100 mm line scales for four sensory traits, tenderness, juiciness, flavour liking and overall liking. In addition, consumers categorised each sample into the following quality grades; unsatisfactory (no grade), good everyday (3 star), better than everyday (4 star), or premium quality (5 star) (Watson *et al.* 2008a).

In order to generate a single score that described the whole of a consumer's eating experience, the four sensory traits were combined into a single palatability or meat quality score (MQ4), by weighting tenderness, juiciness, flavour liking and overall acceptability scores by 0.4, 0.1, 0.2 and

0.3, respectively. These weightings were derived from a discriminant analysis (Watson *et al.* 2008a).

A further step was to relate MQ4 to the consumer assessed quality grades, unsatisfactory (no grade), good everyday (3 star), better than everyday (4 star), or premium quality (5 star). A discriminant analysis was then used to calculate the MQ4 scores that related to the boundaries between each of the quality grades; namely 45.5 for the ungraded and 3 star categories, 63.5 for the 3 and 4 star categories, and 76.5 for the 4 and 5 star categories (Watson *et al.* 2008a).

2.1. Development of a model to predict palatability

Using the MQ4 as the definition of quality, the MSA prediction model was developed using a multiple regression approach. Input variables from the production, processing and value adding sectors were included in a model to predict palatability of individual muscles for a range of cooking techniques. An important feature of the model approach was flexibility, with no single prescribed method to produce a quality product, which is a limitation of the “pathways” approach to quality. Producers have the ability to make management decisions that best suited their stock and local environment, outside of a few critical requirements pre-slaughter. At the processing and retail end, individual cuts each received a quality score for a range of cooking methods and *post-mortem* ageing periods, enabling the processors and retailers to use the products in the way that best fit a variety of different brands and markets. This was desirable, as consumers are not concerned by how palatability scores are derived, rather, that the palatability of the meat matches its description.

The initial MSA model was developed using consumer scores and production and processing data from 12 700 beef samples. The current 2017 version utilises data from over 100 000 consumers and 70 000 beef cuts (Meat and Livestock Australia 2017), and has undergone extensive international testing. The system is regularly updated to reflect current consumer tastes and production methods, which is essential to ensure the quality rating remains relevant and accurate for consumers. For example, the weight of the four sensory scores (tenderness, juiciness, flavour liking, overall liking) used to determine eating quality (MQ4) were modified to apply equal weightings to flavour liking and tenderness, in order to reflect changing consumer preferences. This represents the core MSA philosophy that standards should reflect the consumer and be adjusted as required, while concurrently allowing producers the flexibility to make their own management decisions. This avoids the drawbacks of being prescriptive as to the methods of production (Polkinghorne *et al.* 2008b).

2.2. Components of the beef MSA model

The core of MSA are the CCPs that have been selected on the basis of extensive consumer testing. They are used to manage beef palatability in two ways. Firstly, there is a set of mandatory criteria for carcasses to be eligible for grading; secondly, other CCPs have been incorporated into a continuous grading model to predict palatability for individual combinations of muscle and cooking method. The individual grading of muscles allows MSA to accurately capture CCPs that have a different level of impact on different muscles within a carcass. For example, it is well known that the hanging method used during the chilling disproportionately affects the muscles in the hindquarters, and has relatively little impact on the forequarter muscles. Other factors with a variable impact by muscle are sex, marbling and carcass weight.

A sample output from the MSA model is shown in Fig. 1. The parameters used to predict palatability in MSA are described below:

Percentage of *Bos indicus* The percentage of *Bos indicus* is specified on the producer declaration form. As this is a group value and can be difficult to determine precisely, the accuracy of the measure is increased by also recording the hump height at grading and related to carcass weight. Here, there is the potential to further increase accuracy using genetic information.

Sex The sex category adjusts the palatability score for females and steers. A sex adjustment is applied in two ways. One adjustment is by muscle, with various muscles showing a slight difference between sexes. The second adjustment is applied differentially in conjunction with the ossification score across all muscles. The magnitude of the sex adjustment varies with muscle and is relatively small, being of the order of 2 palatability units. The next commercial MSA model will include an adjustment for bulls.

Carcass weight Carcass weight is used in conjunction with ossification score to estimate the effect of growth rate on palatability. The change in palatability with increased carcass weight differs for each ossification range and tends to decline as ossification score increases. An increase in USDA ossification score from 120 to 200 would change palatability (as measured by MQ4) by approximately 3 units out of a total of 100. The magnitude of the adjustment varies with muscle.

Milk fed veal (MFV) Muscles from calves weaned at approximately 10 months of age immediately prior to slaughter receive a higher score than from earlier weaned cattle of equivalent ossification score. The magnitude of the MFV effect varies with muscle and ranges from 0 to 6 palatability units.

Carcass hanging method The effect of hanging method

Description	Format	Name	Input
Estimated % <i>Bos indicus</i>	% or X if doubt	EPBI	25
Animal sex type	M/F	Sex	M
Hormone growth promotant	Y or ?/N	HGP	N
Milk fed vealer	Y/N	MFV	N
Sale yard	Y/N	SIYrd	N
Rinse/Flush	Y/N	RnFI	N
Hot Std carcass weight	Weight in kg	HSCW	300
Hang method	AT/TS/TL/TC/TX	Hang	TX
Hump height	mm	Hump	40
Ossification USDA	USDA measure	uoss	150
Marbling USDA	USDA measure	umb	350
Rib fat	mm	RbFt	5
Ultimate pH	Metered pH	UpH	5.62
Loin temp at grade	Metered temp C	Utmp	5.2
Days of ageing from kill	Days aged	Age	21

Cut	Muscle	GRL	RST	SFR	TSL	SCT	CRN
Spinalis	SPN081	5	4	5	4		
Tenderloin	TDR034	5		5			
Tenderloin	TDR062	5	5	5	4		
Tenderloin	TDR063	4					
Cube roll	CUB045	4	4	4	4		
Striploin	STA045	4	4	4	4		
Striploin	STP045	4	4	4	4		
Oyster blade	OYS036	3	3	4	4		
Blade	BLD095			2			
Blade	BLD096	3	3	3	3	3	
Chucktender	CTR085		3	3	3	3	
Rump	RMP131	3	4	4	4	4	
Rump	RMP231	3	4	4	4		
Rump	RMP005	4		4	4		
Rump	RMP032			4	4		
Rump	RMP087		3	4	3	3	
Knuckle	KNU066	3	4	3	4	3	
Knuckle	KNU098			3	4	3	
Knuckle	KNU099	2	3	3	3	3	
Knuckle	KNU100			4	4	3	
Outside flat	OUT005		3	3	3	4	3
Outside flat	OUT029			3	4	3	
Eye round	EYE075	3	3	3	3	3	3
Topside	TOP001	3		3	3	3	
Topside	TOP033	3		3	4	4	
Topside	TOP073	2	3	3	4	3	
Chuck	CHK068			3	3	4	
Chuck	CHK074	3	3	3	4	4	
Chuck	CHK078	3	3	3	3	4	
Chuck	CHK081			3	4		
Chuck	CHK082			3	3		
Thin-flank	TFL051			3		3	
Thin-flank	TFL052			4	3		
Thin-flank	TFL064			4	3	4	
Rib-blade	RIB041			3			
Brisket	BRI056			2	3	3	2
Brisket	BRI057			2	3	3	
Shin	FQshin					4	
Shin	HQshin					4	
Intercostal	INT037			3			

Fig. 1 A sample output from the Meat Standards Australia (MSA) cuts based model, showing the inputs used to predict palatability (estimated *Bos indicus* content, sex, hormone growth promotant, milk fed vealer classification, sale yard, carcass weight, hanging technique, hump height, ossification score, USDA marbling score, rib fat depth, ultimate pH, loin temperature, days aged, and selling method, showing in left) and the outputs which comprise predicted grade (3, 4 or 5 star) by cut/muscle and cooking technique (showing in right). Those cells with a cross represent muscle/cooking combinations which failed to grade. Blank cells represent muscle/cooking combinations that have not been tested. For some cuts, different parts of the same muscles are considered. GRL, grill; RST, roast; SFR, stir fry; TSL, thin slice; SCT, casserole; CRN, corning.

varies for individual muscles, with different values for each muscle and hang combination. Hanging methods are AT (*Achilles tendon*), TS (*Tenderstretch from the ligament*), TX (*Tenderstretch from the aitch bone*) and TC (*Tendercut*). The Tenderstretch method was recently adopted by a private French company and used to launch a new premium beef brand (“Or Rouge”) in France. They use Tenderstretch during chilling to improve tenderness of loin and many hind quarter cuts.

Marbling It is well known that intramuscular fat has a positive relationship with the eating quality of beef (Thompson 2002). Currently, there are no commercially viable methods to directly measure intramuscular fat in an abattoir. To compensate for this, two measurements of fatness, marbling score and rib fat, are used to estimate

this relationship within the MSA system. As marbling score and rib fat are positively correlated, the relationship between the two must be accounted for when calculating the palatability grade. This is achieved by evaluating the effect of marbling within defined ranges of rib fat scores. In general, an increase in USDA marble score from 250 to 1190 (equivalent to an increase from about 2 to 20% chemical fat) results in an increase in palatability (as measured by MQ4) of 8 units for the striploin. The magnitude of the adjustment for marbling varies by muscle type.

Ultimate pH Ultimate pH is the pH reached by the *m. longissimus thoracis* after the cessation of metabolic activity post-slaughter. It used both in the calculation of the palatability score, and as a threshold criteria in the MSA system. The threshold for ultimate pH is 5.7, and any

carcasses with an ultimate pH of 5.8 or above are ineligible for grading (Thompson 2002).

Ageing (or conditioning) *Post-mortem* ageing increases the palatability of muscles, although this varies by muscle. Within MSA it is estimated differently for each muscle within each hanging option. Ageing muscles from 5 to 21 d increases the palatability score of the striploin by up to 4 palatability units.

Saleyards Supply of MSA animals is possible from a saleyard if the facilities have been audited and employ best practice for handling animals including a prohibition on mixing of cattle from different sources. If animals are delivered for slaughter through an accredited saleyard system a 5 point penalty is applied to all muscles.

Cooking method Palatability for individual muscles is predicted for a specific cooking method. Larger muscles generally have several cooking options. As would be expected, grilling muscles with low amounts of connective tissue resulted in the highest palatability scores. Roasting muscles with low amounts of connective tissue gave similar scores to grilling, whereas roasting gave muscles with high levels of connective tissue produced much higher palatability scores when compared with grilling. Stir frying and thin slicing gave similar results to grilling for low connective muscles, but relatively high scores in the high connective tissue muscles. The magnitude of the effect of cooking technique on palatability varies with muscle, but can be of the order of 30 palatability units.

Estrogenic and androgenic growth promoting implants Hormone growth promotants (HGP) markedly reduce the tenderness and palatability of beef, though the magnitude varies between cuts (Thompson *et al.* 2008a). The impact of HGP's can be greatly reduced with post-slaughter treatments such as extended *post-mortem* aging and tenderstretch hanging, however the gap cannot be completely eliminated (Dunshea *et al.* 2005). Further work is underway to examine the impact of various types of commercially available HGP on palatability.

New factors under consideration It is important that any grading system continues to improve and evolve with new information and technological advancements, as such this is an important focus of MSA. Recent work has explored the role of genetic information, new cooking methods, and new classes of cattle in order to expand the scope of the MSA system and improve the precision of the quality prediction. For example, bulls are not presently eligible for grading within Australia, and any breed adjustment is limited to *B. indicus* vs. *Bos taurus*. Other measurements include chronological age, to replace ossification score, and biochemical measurements for intramuscular fat and collagen.

Genetic information has the potential to increase the

detail and accuracy of MSA. For example, gene variants within the calpain-system have been reported to influence the *post-mortem* of meat from *B. indicus* animals (Robinson *et al.* 2012) explaining in part the *B. indicus* effect noted by MSA. In contrast, the presence of favourable alleles within the calpain-system increased the tenderness of the striploin by 3 to 6 palatability units. The inclusion of such genetic information in the MSA system in the future will encourage producers to include these alleles in their breeding strategies thereby further improving the accuracy of the MSA grading system. The inclusion of this information in the MSA system may be facilitated by the development of certified lines of cattle, which possess the favourable alleles, and/or testing at slaughter as the cost of these tests decrease.

It was recently shown that there are only small relationships between biochemically measured intramuscular fat and collagen with untrained consumer scores for beef quality within particular muscles, despite strong relationships when a range of different muscles are tested (Chriki *et al.* 2013; Bonny *et al.* 2015). This indicates that the biochemical profiling of muscles is unlikely to provide extra predictive power for predicting eating quality where muscle type is already known.

As animals mature, the tenderness of meat decreases, particularly due to collagen cross-linking changing the thermal stability of the collagen and its persistence during cooking (Bailey 1985). To estimate this effect, the MSA system uses an ossification score, which is a measure of bone maturity and a proxy for animal maturity (Watson *et al.* 2008b). As an alternative, Bonny *et al.* (2016c) explored the relationship between chronological age and eating quality. They demonstrated that animal age has no relationship with eating quality for carcasses from animals less than 3 years old, therefore it would not add value to the current MSA system in Australia. However, where animals were older, and more skeletally mature, ossification score is much less useful in the quantification of eating quality and animal age would increase the precision of a quality-based grading system.

Sex is a factor known to influence the eating quality of meat (Boccard *et al.* 1979; Seideman *et al.* 1989; Chriki *et al.* 2013). However, currently only steers and female cattle are eligible for grading in the MSA system. Bonny *et al.* (2016a) demonstrated that the eating quality of beef from bull carcasses was accurately predicted by the current factors in the MSA system. However the quality was slightly overpredicted when compared to female or steer carcasses. This work implies that a "bull factor" would be required if bulls were to become eligible for grading in MSA, or a similar-type system. Breed is also known to affect eating quality, but at present the only breed adjustment defined in the MSA system is for *B. indicus* vs. *B. taurus*.

Differences between dairy and beef breeds (Lizaso *et al.* 2011) and across beef breeds (Cuvelier *et al.* 2006) have been well documented, although it was expected that the majority of differences between breeds could be accounted for with standard carcass measurements, such as carcass weight and marbling. However, the results from Bonny *et al.* (2016a) demonstrated that even after correcting for these standard carcass measurements, a number of cuts from dairy breeds still had better eating quality scores than those predicted by the MSA model. This indicates that a positive adjustment for dairy breed type would improve the accuracy of the MSA system for these cattle.

The type of packaging used to store and display meat can also have significant effects on eating quality. One system known to reduce the eating quality of lamb and beef steaks is high oxygen (80%) modified atmosphere packing. Published data in lamb (Frank *et al.* 2017) shows a decline of 5–10 palatability units of a total of 100 after extended display time, assessed using MSA sensory protocols.

3. Added value to the industry and the carcass at retail

The success of the MSA system has been driven by the added value to the beef industry achieved by supplying better quality beef, and appropriately labelled beef to consumers (Polkinghorne *et al.* 2008a; Griffith and Thompson 2012). In 2016, there was an average price premium for MSA compliant carcasses of AUD\$0.24 kg⁻¹ (Meat and Livestock Australia 2016b). It is notable that the highest price premiums were observed among the cuts with the highest eating quality (Fig. 2 showing a retail premium of AUD\$4.33 kg⁻¹ for tenderloin), suggesting that eating quality is a main driver of variation in the price differentials. An average of 40% of these retail premiums are delivered back to beef producers, adding value throughout the supply chain (Polkinghorne *et al.* 2008a). Through this mechanism, there was an estimated AUD\$153 million returned to producers from retail premiums for 3.1 million MSA graded carcasses in the 2015/2016 financial year. This added value can be further broken down to an average of AUD\$66 per head for grass fed and AUD\$45/head for grain fed cattle. The last extensive review of the MSA system was performed in 2016 where the industry impact and benefit:cost ratio was calculated as AUD\$679 million and 12.5:1 in a 5-year performance review between 2010 and 2015 (Meat and Livestock Australia 2016a).

Of most interest to livestock producers is the pricing of the carcass based on the summation of the weight of individual cuts by price according to their eating quality (Meat and Livestock Australia 2011). To determine this, the economic weights for the various quality traits were calculated from a

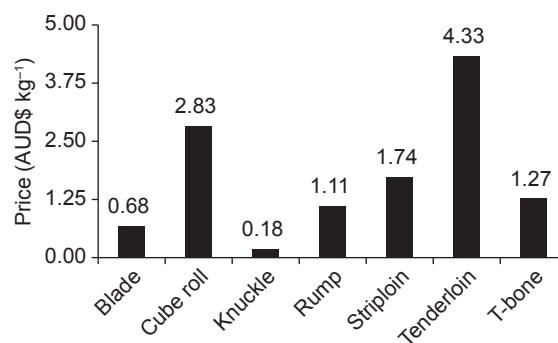


Fig. 2 Average price differentials for Meat Standards Australia (MSA) graded beef by cut in the 2015/2016 financial year in Australia (adapted from Meat and Livestock Australia 2016b).

dataset of 423 carcasses (Doljanin 2013). Given differences in quality and yield, the value of the carcasses at retail when expressed in AUD\$ kg⁻¹ hot carcass weight, ranged from AUD\$2.15 to 3.16 kg⁻¹. From this data set, it was calculated that tenderstretch resulted in an increase of AUD\$0.27 kg⁻¹, and as expected, this could be completely attributed to improvements in eating quality, with no impact of carcass yield. Additionally, the economic weight of the traits that the producer can either influence by management decisions or breed were calculated. For this data set, an increase in 100 units of ossification score resulted in AUD\$0.15 kg⁻¹ decrease in value, and again, this effect was independent of carcass yield. For marbling, a 100 unit increase in marbling score resulted in a AUD\$0.07 kg⁻¹ increase in carcass value and this increased to AUD\$0.09 kg⁻¹ when variation in carcass yield was taken into account. This was because, although an increase in marbling was associated with increased quality, it was also associated with decreased yield. At the same carcass yield, the effect of marbling on value was greater. Fat depth at the 12/13th rib had a negative effect on carcass value with a 1 mm increase in fat depth associated with AUD\$0.018 kg⁻¹ decrease in carcass value. As expected the negative effect of fat depth was largely associated with decreased carcass yield.

On average, the average price differential for MSA young non-feedlot cattle across all weight ranges was AUD\$0.24 kg⁻¹ (Fig. 3). Consequently, MSA beef producers potentially received an additional AUD\$66 per head for young non-feedlot cattle. The added value was AUD\$45 per head for cattle that meet the grainfed specifications, totalling an estimated AUD\$153 million delivered back to the farm gate (Meat and Livestock Australia 2017). This analysis provides clear market signals for the producer to implement either genetic or management programs to change carcass traits. Importantly it also represents the first time that producers have received price differentials for the eating quality of their cattle. With this information, the price of

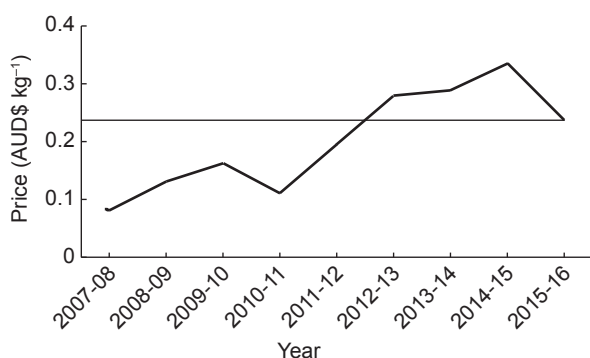


Fig. 3 Price differentials for Meat Standards Australia (MSA) young cattle (adapted from Meat and Livestock Australia 2017).

a new bull to increase marbling in slaughter progeny can be compared with the expected change in value of these progeny. Similarly, feedlotting enterprises can calculate the returns on carcass value for days on feed based on the expected impact on carcass weight, marbling, fat depth and ossification; optimising their feeding management according to updated market values and the cost of feed. Finally, producers have to forecast fluctuations on beef prices, especially on premium products (Morales *et al.* 2017).

4. Lamb and sheepmeat MSA eating quality model

4.1. Development

Similar to the trend seen in beef, lamb consumption also declined in Australia during the twentieth century in part due to inconsistent products for satisfying consumer needs (Russell *et al.* 2005). In an attempt to maintain strong consumer demand and improve lamb and sheepmeat quality, a series of experiments were undertaken to determine the CCPs contributing to lamb and sheepmeat eating quality. These utilised the MSA sensory protocols developed for beef with some modifications to account for the smaller size of lamb and sheep cuts. The major conclusions were published as a series of scientific papers in the *Australian Journal of Experimental Agriculture* (Pethick *et al.* 2005; Pleasants *et al.* 2005; Thompson *et al.* 2005a, b).

4.2. Components of the lamb and sheepmeat MSA model

Currently the MSA program for lamb and sheepmeat is a supply chain system, with all sectors having to comply with guidelines for best practices of feeding, handling and curfew management, slaughter protocols (pH decline), product ageing, and retail presentation of lamb cuts (Pethick *et al.*

2005; Young *et al.* 2005). The details are publicly available on the Meat and Livestock Australia web site (www.mla.com.au) and the process has been shown to dramatically reduce the variation in objective measure of tenderness (Pethick *et al.* 2006a).

A general description of the guidelines are as follows: Lambs must be sourced from MSA registered producers, with training required for registration. Lambs must not have changed properties or undergone selected management procedures (shearing or drenching) for at least two weeks prior to slaughter. There are no breed restrictions, however there is a higher recommended growth rate for Merinos (150 g d⁻¹) than for cross breed lambs (100 g d⁻¹) in the three weeks pre-slaughter, to offset the increased rates of high ultimate pH or dark cutting meat seen in merinos (Gardner *et al.* 2014). To be classified as lamb, a carcass must have no erupted permanent incisor teeth, the hot carcass weight must be greater than 18 kg and a Grade Rule (GR) tissue depth (a measure of carcass fatness) of at least 5 mm. The recommendations for pH decline and temperature post-slaughter vary for short (5–10 d) and long (>10 d) aged products, with short aged lamb requiring electrical stimulation. At retail, all cuts are acceptable for grilling or roasting, except the isolated topside (*m. semimembranosus*) which is eligible for grading only as a stirfry or slow wet cook.

4.3. Where to next?

Although successful in improving the eating quality, the existing lamb and sheepmeat MSA program has been a simpler mob based ‘in or out’ system that has lacked individual carcass grading or cut by cook grading. There are many limitations to this structure and as such, the lamb and sheepmeat model is currently being extended into a cuts-based system similar to the MSA model for beef. This has been based on large scale studies using the MSA sensory sheep protocols (Thompson *et al.* 2005a) with over 7 000 untrained consumers assessing the eating quality of two muscles (*m. longissimus lumborum* and *m. semimembranosus*) from over 2000 lambs representing 223 sires from Terminal, Maternal and Merino sire types. Much of this research has been published as a 2014 special edition in *Meat Science* (Mortimer *et al.* 2014; Pannier *et al.* 2014a, b). In brief, these results have shown that even with best practice, there is still variation in eating quality of up to 20% in the loin of graded lambs. However, it was demonstrated that through knowledge of five characteristics, breed type, carcass weight, a measure of lean meat yield, and intramuscular fat, a MSA-type model could be used to predict the eating quality of both loin and topside. The precision (data unpublished) is similar to the MSA grading

scheme in beef, which accounts for a mean of 67% of the variance in eating quality in Australia and also in a number of European countries (Bonny *et al.* 2017). This highlights that it is possible to design an accurate cuts-based grading model for lamb and sheepmeat, similar to the system currently used for beef.

As part of extending the sheepmeat MSA system to include cut by cooking method based, trials with new cooking techniques, alongside grilling and roasting, have commenced. For example, the traditional style Chinese hot-pot method (or locally referred to as ‘Huoguo’) is being tested to determine the suitability of specific Australian sheep cuts for this style of cooking for the Chinese market. Traditionally the meat used in hot-pot cooking is fabricated using varying proportions of fat and muscle and subsequently thinly sliced prior to cooking. To best replicate traditional hot-pot meat as a potential commercial product, boneless lamb and sheepmeat shoulders and hind quarters (excluding the topside muscle) have been trialled through the sensory testing of 1.6 mm width slices, cooked for 2 min in boiling water. These data are currently being analysed.

Furthermore, the sheep quality grades are also classified unsatisfactory (no grade), good everyday (3 star), better than everyday (4 star), or premium quality (5 star), aligning with the current MSA grades for beef. However, at present there is no distinction made between the 3-, 4- and 5-star graded products in terms of quality and corresponding price points. Therefore, by making use of these star grades, there is scope for the sheepmeat MSA system to add further value to the Australian sheep industry. The increase in value would come from consumer’s willingness to pay for higher quality products as research has shown that Australian consumers are willing to pay 1.43 and 1.90 times more for the 4- and 5-star quality, relative to the 3 star (Tighe *et al.* 2017). This highlights the need for future MSA sheepmeat quality differentiation and pricing applications that align with the different customer satisfaction levels.

5. International development of the Meat Standards Australia system

As reviewed by Hocquette *et al.* (2014) and Pethick *et al.* (2018), various other countries or regions of the world have also conducted consumer panels utilising MSA protocols. These countries include: New Zealand (Crowover *et al.* 2017), Korea (Thompson *et al.* 2008b), the USA (Smith *et al.* 2008), France (Hocquette *et al.* 2011), Japan (Polkinghorne *et al.* 2011), Poland (Bonny *et al.* 2016b), South Africa (Thompson *et al.* 2010), Northern Ireland (Bonny *et al.* 2016b; Bonny *et al.* 2017; Devlin *et al.* 2017; McCarthy *et al.* 2017) and the Irish Republic (Allen 2015) for beef, and China and the USA for lamb and sheepmeat (O’Reilly *et al.* 2016).

5.1. Beef

The results of international consumer testing for beef can be seen in Tables 1 and 2. The overall conclusion is that consumers often assess the eating quality of beef in a similar fashion, despite some small differences in the weightings applied to flavour liking and tenderness (Bonny *et al.* 2017) (Tables 1 and 2).

Japanese consumers readily identified distinct differences in the eating quality of beef samples, and this was consistent for all cooking methods (Polkinghorne *et al.* 2011). The only variation present was seen in the importance of the different sensory traits between the different cooking methods, with tenderness rated as most important for grill, and liking of flavour most important for the Japanese beef preparation methods of Yakiniku and Shabu Shabu. However, it can be seen in Table 2 that specific Asian cooking methods did not significantly change the final assessment of beef by Japanese consumers. Similar results were found in South Korea with the cut-offs for traditional cooking methods aligning well with results for grill (Table 2) (Thompson *et al.* 2008b).

The weightings calculated to generate a single quality score (e.g., the MQ4 score) varied between countries. In most cases, overall liking was most important, with juiciness having the least importance (Table 1). Interestingly, the largest variation was reported in the importance of tenderness and flavour liking between the different countries. This may reflect differences in the consumers or differences in the production methods in the countries changing the perception or the actual quality of the beef.

Cooking method had little effect in South Africa, where the beef industry has many similarities with Australia. In the study by Thompson *et al.* (2010), there were high correlations between all sensory scores for all groups, and with only subtle differences between the urban and rural consumers (Tables 1 and 2).

Consumers from the USA had similar cut-offs to consumers from all other countries examined (Table 2) (Smith *et al.* 2008). Because of the limited data evaluating the suitability of the MSA system in America, it is impossible to draw a solid conclusion, but the format of the MSA taste panels performed well with American consumers and their responses followed a similar trend to those generated by Australian, South Korean, Japanese and French consumers.

In France the industry was concerned that a MSA-like system would not suit the complexity of the French beef industry and market, and due to the presence of existing quality labels (Hocquette *et al.* 2011). However, recent experiments have demonstrated the robustness of the system and garnered interest from the private sector. Indeed, the accuracy of prediction of the final ratings by the French

Table 1 Optimal weightings of sensory scores overall, and for each country from a discriminant analysis using the sensory scores to allocate beef to quality grades

Country	Cook type	Other specification	Weighting of sensory score ¹⁾				Reference
			Tn	Ju	Fl	Ov	
South Africa		Region					Thompson <i>et al.</i> (2010)
	Grill	Urban	0.18	0.20	0.26	0.36	
	Slowcook		0.21	0.16	0.24	0.39	
	Grill	Rural	0.21	0.23	0.27	0.29	
Japan	Slowcook		0.26	0.08	0.25	0.40	Polkinghorne <i>et al.</i> (2014)
	Grill		0.30	0.20	0.24	0.26	
	Yakiniku		0.25	0.06	0.41	0.28	
France	Shabu Shabu		0.16	0.20	0.40	0.24	Legrand <i>et al.</i> (2013)
		Cooking doneness					
Ireland	Grill	Medium	0.33	0.02	0.32	0.33	Bonny <i>et al.</i> (2016b)
	Grill	Rare	0.31	0.01	0.34	0.36	
Northern Ireland		Cooking doneness					Bonny <i>et al.</i> (2016b)
	Grill	Medium	0.31	0.10	0.35	0.24	
	Roast	Medium	0.21	0.16	0.27	0.36	
Poland	Korean BBQ	Medium	0.24	0.07	0.42	0.27	Bonny <i>et al.</i> (2016b)
		Cooking doneness					
	Grill	Medium	0.29	0.08	0.34	0.28	
	Grill	Well done	0.29	0.08	0.33	0.30	
Poland	Roast	Medium	0.21	0.10	0.39	0.30	Bonny <i>et al.</i> (2016b)
	Roast	Well done	0.19	0.12	0.35	0.34	
		Cooking doneness					
	Grill	Medium	0.23	0.04	0.42	0.32	
Poland	Roast	Medium	0.18	0.06	0.43	0.33	Bonny <i>et al.</i> (2016b)
	Slow cook	Medium	0.25	0.13	0.35	0.28	

¹⁾ Tn, tenderness; Ju, juiciness; Fl, flavour liking; Ov, overall liking.

Table 2 Grade boundaries calculated from the discriminate functions for the optimally weighted sensory scores (from Table 1)

Country	Cook type	Other specification	Boundary between quality grades (stars)			Reference
			2 to 3	3 to 4	4 to 5	
South Africa		Region				Thompson <i>et al.</i> (2010)
	Grill	Urban	42	62	78	
	Slowcook		41	61	79	
	Grill	Rural	43	60	72	
Japan	Slowcook		42	58	70	Polkinghorne <i>et al.</i> (2014)
	Grill		40.4	66.8	83.1	
	Yakiniku		43.4	68.5	83.9	
France	Shabu shabu		43.7	67.4	83.4	Bonny <i>et al.</i> (2016b)
		Cooking doneness				
Ireland	Grill	Medium	35.98	61.04	80.14	Bonny <i>et al.</i> (2016b)
	Grill	Rare	36.98	61.66	81.47	
	Grill	Medium	39.66	60.42	76.94	
Northern Ireland	Roast	Medium	41.56	60.27	72.36	Bonny <i>et al.</i> (2016b)
	Korean BBQ	Medium	42.33	65.54	81.71	
	Grill	Medium	40.56	57.51	69.79	
Poland	Grill	Well done	36.23	58.75	75.86	Bonny <i>et al.</i> (2016b)
	Roast	Medium	37.63	60.35	76.26	
	Roast	Well done	35.38	57.57	74.6	
	Grill	Medium	42.51	60.77	74.56	
Poland	Roast	Medium	41.88	62.18	77.38	Bonny <i>et al.</i> (2016b)
	Slow cook	Medium	41.65	60.83	75.15	
USA	Grill and Roast	Medium	41–43	65–66	82–83	Smith <i>et al.</i> (2008)
South Korea	Grill		48	66	78	Polkinghorne <i>et al.</i> (2011)
	South Korean BBQ		52	69	81	

consumers using the MSA weighted eating quality score was over 70%, which is similar to the Australian experience (Bonny *et al.* 2016b). The results for beef cooked “rare” and “medium” were also very similar (Legrand *et al.* 2013). The French consumers had a lower MQ4 score boundary between unsatisfactory and good-every-day than all of the other countries studied here and previously (Hocquette *et al.* 2014; Bonny *et al.* 2016b). Yet, they also had one of the highest upper boundaries between better-than-every-day and premium, similar to those reported for the Japanese (83.1) and Australians (Table 2) (Hocquette *et al.* 2014). As the experiment was designed to present all consumers with meat of a range of qualities, these boundaries indicate that the French consumers have a greater propensity to use the whole scale when scoring meat. In contrast, Polish consumers tended to avoid the extreme ends of the scale and the consumer scores are more likely to cluster around the middle (Legrand *et al.* 2017). However, the high accuracies of the discriminant analysis overall, indicates that the technique is able to account for minor variation in the use of the scale between demographic groups and is unlikely to be an important factor in the prediction of eating quality (Bonny *et al.* 2017). Based on these results and an unpublished experiment, a new French beef brand called “Or Rouge” was launched at the end of 2016.

Beef is mainly produced from steers and heifers from beef breeds in Australia. However, in Europe, beef is produced from cows, heifers, steers and young bulls, which are either beef or dairy breeds. These exist in various proportions depending on the European country: for example, more than half of beef meat comes from cows in France or from young bulls in Poland. Therefore, a study was recently carried out to examine the effects of sex and breed type on the prediction of eating quality using the MSA grading scheme (Bonny *et al.* 2016a). Overall, the MSA system was able to predict beef eating quality from all types of beef. However, beef from young bulls had slightly lower MQ4 scores than beef from steers and females (Fig. 4), and eating quality of beef from young bulls was predicted less accurately by the MSA model (Bonny *et al.* 2016a). In addition, beef from beef breeds had slightly lower eating quality scores than beef from dairy breeds and crosses for five out of the 16 muscles tested (Bonny *et al.* 2016a). This result demonstrates that a separate ‘bull’ adjustment would be required if bulls were eligible for grading as the difference could not be completely accounted for by other carcass measurements such as ossification score and marbling.

Lastly, in most European countries (Bonny *et al.* 2017), as well as in the USA (Smith *et al.* 2008), South Africa (Thompson *et al.* 2010), and Japan (Polkinghorne *et al.* 2011), consumers were willing to pay between 1.5 and 2 times more for the 4- and 5-star quality, relative to the 3 star

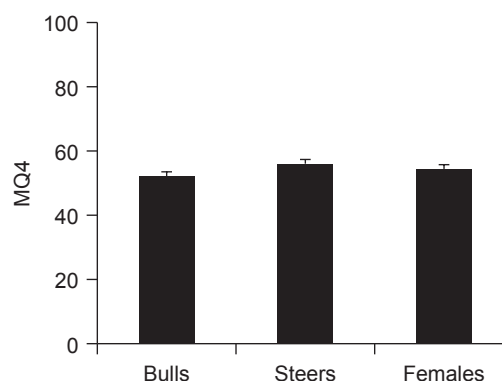


Fig. 4 Meat quality score (MQ4) values for beef from 85 young bulls, 255 steers and 171 females from France, Poland, Northern Ireland, Ireland and Australia (Bonny *et al.* 2016a).

and half less for unsatisfactory beef compared to the 3 star. Furthermore, demographic factors have only minor effects on consumer scores and willingness to pay. For instance, men scored beef about 2% higher than women in most countries (Bonny *et al.* 2017).

The overall conclusion that can be drawn from this work is that consumers from many different countries and cultures have similar responses for the assessment of beef quality when the MSA system is used to assess preferences. However, some minor adjustments are sometimes required to reflect, with a better accuracy, preferences of consumers in some countries and more importantly, to predict more accurately beef eating quality from young bulls and from the different breed types. Therefore, scientists from six countries have decided to merge all the data obtained with the MSA consumer testing protocols to develop a global database. To achieve this goal, a Foundation under the name, “International Meat Research 3G Foundation” was established in 2017. Its purpose, in addition to hosting the database, is to add MSA grading inputs and MSA consumer testing protocols to the research in eating quality worldwide (Pethick *et al.* 2018).

5.2. Lamb and sheepmeat

To date, consumer taste panels utilising MSA protocols for lamb and sheepmeat have only been carried out internationally in two of Australia’s strongest sheepmeat export markets, China and the USA. Predicted mean eating quality scores from grilled lamb when comparing untrained Australian, Chinese and American consumers for the four eating quality traits (tenderness, juiciness, flavour liking and overall liking), for both loin and topside cuts are presented in Table 3.

The overall liking scores of Australian lamb samples

Table 3 Predicted lamb eating quality for sensory traits for loin and topside for Australian, Chinese and American consumers

Sensory trait	Cut	Australia	China	USA
Tenderness	Loin	71.2±1.7	69.4±1.7	76.1±1.6
	Topside	56.9±1.7	52.4±1.6	58.1±1.6
Juiciness	Loin	67.2±1.2	68.7±1.2	68.8±1.2
	Topside	57.3±1.2	57.0±1.2	57.9±1.2
Flavour liking	Loin	68.9±0.9	67.9±0.9	68.3±0.9
	Topside	58.6±0.9	57.5±0.9	61.0±0.9
Overall Liking	Loin	71.5±1.2	71.2±1.2	70.6±1.2
	Topside	58.6±1.2	58.3±1.2	60.2±1.2

Data expressed as eating quality scores (0–100) (mean±SE) were from O'Reilly *et al.* (2016).

were consistent for Australian, Chinese, and American consumers ($P>0.05$) (O'Reilly *et al.* 2016). Similarly, the perceived juiciness of Australian loin and topside samples was similar for all consumer groups. As for tenderness, Chinese consumers scored tenderness up to 5 units lower out of a total of 100 than American consumers. These lower eating quality estimates likely reflect inexperience with the “Western” style of cooking compared to traditional style Chinese meals which mainly consist of finely sliced or very small portions of proteins. With China's increasing interest in western culture and access to disposable incomes, exposure to, and ultimately acceptability of a “thicker”, “Western” style steak is likely to ensue.

Further detailed analysis of the combined eating quality scores, the accuracy of their prediction within each country, and the impact of culinary preferences will yield more conclusive results on the success of the lamb and sheepmeat MSA grading system in China and the USA in the future.

6. Conclusion

As demonstrated in this review, the MSA grading system is a quality assurance system capable of managing and predicting beef and sheepmeat palatability, not only in Australia but also in many other countries from different parts of the world particular for beef. One of the keystones of the system is the use of CCPs which impact on palatability. Importantly, these CCPs have been defined and quantified using large scale consumer taste panels. There are CCPs in every stage of the chain, from production, transport, and slaughter to post-processing. Together, these CCPs are used as input factors into the MSA grading system to generate a palatability score. The model provides a multitude of pathways to achieve a defined quality outcome, allowing producers to make decisions that best suit their production strategies. This is effective as the important aspect for consumers is that the expected quality matches their eating experience, as long as handling of the animal/carcass along the red meat supply chain meets welfare and

food safety standards. This also gives scope for branded products to use the grading system, while still retaining the ability to differentiate themselves in the market place with particular methodologies, for example “Certified Angus Beef” or “Prime Dorper Lamb”. There are now plans in place to create an international database combining national MSA beef datasets from all of the different countries where it has been tested.

The key to the financial success of the MSA system will be to use it to underpin value based trading for beef. Research is in progress to recalculate carcass value by summing value of all cuts in the carcass. This may provide a new transparent pricing system, which sends clear economic signals to the producer as to the relative merit of various carcass traits. Experience has demonstrated that producers are very responsive to change when appropriate economic signals are received.

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