Final report

Comparison of USDA and MSA Graded Beef

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Abstract

This experiment was designed to compare eating quality and appreciation of Meat Standards Australia (MSA) 5 Star, 4 Star and 3 Star graded beef against USDA Prime, Choice and Select graded beef using 240 untrained Japanese consumers. There were 72 USDA cuts and 72 MSA cuts consumed with even numbers in each quality category. Tenderloins and the *longissimus* muscle of the cube roll were served for USDA Prime and MSA 5 Star product while striploins and the *longissimus* muscle of cube rolls were served for USDA Choice, USDA Select, MSA 4 star and MSA 3 star. All cuts were aged for 30 ± 3 days post-mortem. The demographics of the 240 consumers were a great cross section of Japanese society accurately reflecting the country's appraisal of meat.

The MSA grill protocol was utilised with all 25mm steaks being served at medium doneness. Each sample was consumed by 10 consumers. Each consumer sampled 7 steaks (1 of each USDA and MSA quality grades plus a link sample) and scored them on a 100-point line scale for tenderness, juiciness, flavour and overall liking. These terms were weighted at 0.3, 0.1, 0.3 and 0.3 respectively to make a meat quality (MQ4) score for each sample.

The results showed that Japanese consumers are willing to pay 138% and 61% more MSA 5 Star and MSA 4 Star graded beef compared to MSA 3 Star beef which is great incentive to utilise a eating quality prediction model like MSA to deliver consistency to consumers.

The consumer data showed that the MSA quality grading system delivered the highest MQ4 score for 5 Star "Premium Quality" beef which was higher than all other quality grades including USDA Prime when tenderloin and cube roll scores were combined ($P<0.05$). USDA Prime had an equal MQ4 score to MSA 4 Star "Better than Everyday Quality" beef. MSA 3 Star "Good Everyday Quality" beef ranked equal to USDA Choice, while USDA Select quality beef had significantly lower MQ4 scores than all other quality grades ($P<0.05$). These results are indicative of the ability of the MSA and USDA grading systems to segregate cuts on quality and are based on 144 commercially available cuts, and future results may vary.

The MSA cuts-based grading system which takes into consideration all breed, management and carcass variables which are known to impact eating quality delivers greater accuracy and consistency of product quality across cuts delivered to consumers when compared to carcass-based grading systems like that utilised by the USDA. There were large differences seen between cuts of the same USDA grade as some factors like HGP and beta-agonist inputs have cut specific impacts which are not accounted for in a carcass-based model.

Executive Summary

Background - The USDA beef quality grade is a categorical, carcass-level descriptor based primarily on marbling and physiological maturity/ossification or dentition. By contrast, Meat Standards Australia (MSA) is a consumer-calibrated prediction system that models eating quality for specific cut by cook combinations using a multivariate model trained on large-scale untrained consumer taste panel data. The number of input variables in the MSA model are extensive in an effort to explain the complex biology of meat quality. The purpose of this project was to demonstrate, through consumer testing in market, that the more complex MSA grading system delivers less variation between cuts in a given quality level than the USDA grading system.

Objectives - Evaluate the comparison between 3 USDA grades and 3 MSA beef grades based on quality, sourcing product from USA and Australia commercial supply chains, delivered directly to market.

Methodology - Twenty-four samples of each quality grade were consumer tested (72 USA and 72 Australian) equalling 144 samples in total. These 144 samples were consumer tested by 240 Japanese consumers using MSA grill protocols, whereby consumers rank each sample for tenderness, juiciness, flavour and overall liking on a 100 point scale line. Each sample was eaten by 10 different consumers. Demographic data was also gathered for the consumers along with their willingness to pay for beef of varying quality.

Results/key findings - The results showed that Japanese consumers are willing to pay 138% and 61% more for MSA 5 Star and MSA 4 Star beef compared to MSA 3 Star, which is great incentive to utilise an eating quality prediction model like MSA to deliver consistency to consumers. The consumer data showed that the MSA quality grading system delivered the highest MQ4 score for 5 Star “Premium Quality” beef which was higher than all other quality grades including USDA Prime when tenderloin and cube roll scores were combined ($P<0.05$). USDA Prime had an equal MQ4 score to MSA 4 Star “Better than Everyday Quality” beef. MSA 3 Star “Good Everyday Quality” beef ranked equal to USDA Choice, while USDA Select quality beef had significantly lower MQ4 scores than all other quality grades ($P<0.05$).

Carcass based grading systems which only account for marbling and physiological maturity do not deliver cuts with a guaranteed quality to consumers as they do not account for all the factors that influence eating quality like *Bos indicus* content, HGP status and beta agonist usage which all negatively impact meat quality, plus their impact varies for different cuts. The results clearly show that a cut-based system delivers the same quality into MSA quality grades accurately regardless of cut ensuring that consumers do not need knowledge of muscle variation across a carcass to purchase the correct beef for their meal. Hence, consistency in quality between cuts can only be guaranteed by MSA, not carcass level grading systems.

Benefits to industry - This research provides insight and evidence for exporters of Australian MSA graded beef to compare MSA 5, 4 and 3 Star quality cuts to USDA Prime, Choice and Select quality cuts. This is very useful when marketing beef in international markets where both Australia and the USA are volume exporters.

Future research and recommendations - Future R&D could revolve around a comparison of similar MSA graded lamb or beef products in other important international markets. Recommendations are

to provide these comparison results to all exporters of MSA graded beef and to further explore the division of the MSA 3 Star quality grade (MQ4 46 to 63 points) into 2 different quality grades.

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1. Background

The USDA beef quality grade is a categorical, carcass-level descriptor based primarily on marbling score in the longissimus at the quartering site and physiological maturity/ossification or dentition. The USDA quality grade for a carcass functions as a proxy for expected palatability across the carcass. By contrast, Meat Standards Australia (MSA) is a consumer-calibrated prediction system that models eating quality for specific "cut × cooking method" combinations using a multivariate model trained on large-scale untrained consumer taste panel data. The number of input variables in the MSA model are extensive in an effort to explain the complex biology of muscle impacted by varying production systems, genetics and processing management which all impact eating quality. The MSA model is outcome-based and cut-specific (Polkinghorne et al., 2008; Watson et al., 2008a; Watson et al., 2008d).

Evidence accumulated over decades shows that, while marbling is positively associated with consumer liking, it alone is a weak to moderate predictor explaining only around 15% of variation in consumer scores (Nguyen et al., 2021). Both USDA and MSA grading systems rely on the *M. Longissimus thoracis* as the indicator muscle which is problematic because correlations in tenderness between the *Longissimus* and other muscles are low to moderate and highly muscle-dependent. These limitations explain why carcass-level grades imperfectly rank eating quality across diverse muscles and cooking methods.

MSA explicitly addresses these sources of biological and processing variation. The prediction model integrates predictors including intramuscular fat/marbling, ossification (as a proxy for physiological age/collagen cross-linking), carcass weight and rib fat, hump height as the indicator of *Bos indicus* content (when adjusted for sex and weight), sex class, hormonal growth promotant (HGP) status, ultimate pH, post-mortem suspension (achilles hung or tenderstretched), days aged post-mortem, and—critically—the cut and intended cooking method (McGilchrist et al., 2019). Consumer sensory data are combined into a composite meat quality score outcome that weights tenderness, juiciness, flavour liking and overall liking called MQ4. The weightings are 0.3 for tenderness, 0.1 for juiciness, 0.3 for flavour liking and 0.3 for overall liking. The MSA system then predicts the probability of meeting defined consumer satisfaction thresholds for each cut × cook with ungraded defined as <46 points, 3 star "good everyday" defined as 46 to 63 points, 4 star "better than everyday" 64 to 75 points and "exceptional quality" ≥76 points. The MSA system is a consumer-validated prediction of palatability for 39 cuts across the carcass (McGilchrist et al., 2019).

In contrast, the USDA grading system does not take into consideration factors which have a known impact on meat quality like hump height as the indicator of *Bos indicus* content (Thompson, 2002), hormonal growth promotant (HGP) status (Lean et al., 2018), beta-agonist status (Lean et al., 2014), post-mortem suspension (Park et al., 2008), days aged post-mortem (Thompson et al., 2006), along with the cut/muscle and intended cooking method (Thompson, 2002; Watson et al., 2008c). Moreover, the USDA has made recent changes that allows dentition and/or age documentation to be used as alternative methods for current determination of carcass maturity moving away from ossification. Cattle with 2 or less permanent incisors are deemed less than 30 months of age which fits them into the A-maturity category for USDA Quality Grading regardless of ossification score. This could potentially add variation to eating quality also.

Genotype effects (Bos indicus influence captured via hump height/weight) and HGP use both depress eating quality on average due to their impact increasing calpastatin and suppressing post-mortem ageing/proteolysis (Packer et al., 2018; Packer et al., 2021a). MSA therefore applies

evidence-based adjustments, recently refined to avoid double-counting effects across muscles (Packer et al., 2021b). Ageing time further interacts with these factors, improving myofibrillar tenderness but with diminishing returns depending on pH, muscle, and growth-promotant history (Packer et al., 2021a). Collectively, these relationships explain why multivariate, cut-specific prediction achieves better consumer alignment than a carcass-level visual grade which ignores important factors, which change muscle physiology and have a known impact on eating quality.

Practically, the consequence is that each carcass contains cuts which span different quality grades under different cooking methods and the single USDA quality grade anchored to the carcass does not describe those cut and cooking method differences well. Additionally, consumers buy meals or cuts, not carcasses. MSA's cut-by-cook predictions allow more precise sorting, ageing, and cooking recommendations, whereas USDA grades remain useful as a broad market signal but less discriminating for muscles and cookery diverging from the ribeye benchmark (Smith et al., 2008). The complexity added to the MSA prediction model for cuts-based grading is designed to ensure that consumers are delivered a meal that eats as predicted.

The purpose of the project was to demonstrate, through consumer testing in market, that the more complex Meat Standards Australia (MSA) system delivers less variation in a given quality level than the USDA grading system. The same cuts, post-mortem ageing periods and cook method were utilised to minimise the impact of non-biological factors impacting on consumer sensory scores.

2. Objectives

Evaluate, using Japanese untrained consumers, the eating quality of 3 USDA and 3 MSA beef grades , sourcing product from US and Australian commercial supply chains.

3. Methodology

Japan was nominated as the location for this in-market research, since primals imported from both the USA and Australia could be sourced easily through commercial supply chains, representing the USDA and MSA grade categories and aged for similar periods of time.

For this research, cuts sourced through commercial supply chains were aged for a similar period of time prior to consumer testing (Table 1). Other commercial brand specifications such as feed type, breed or age were not requested when sourcing the product. Twenty four cuts of each quality grade were consumer tested (72 USA and 72 Australian) equalling 144 samples in total. Other than cut and quality level, there was no breed or finishing system specifications for the samples. These 144 samples were consumer tested in 4 sessions of 60 consumers, totalling 240 Japanese consumers. Each sample was consumed by ten different consumers. The consumer testing was conducted in collaboration with MLA Japan in Tokyo, utilising a commercial further processing facility, kitchen and amenities.

Consumer sessions were conducted using MSA grill protocols (Watson et al., 2008a), whereby consumers rank each sample for tenderness, juiciness, flavour and overall liking on a 100 point scale line. Each consumer ate and scored 7 samples in total.

- 1 x link sample
- 2 x high quality (USDA Prime and MSA 5 star)
- 2 x medium quality (Choice and MSA 4 star)

o 2 x lower quality (Select or standard and MSA 3 star)

3.1 Meat procured

The meat utilised for the experiment came from Australia (GrainFed and non-GrainFed) and the USA. The high quality meat was 12 tenderloins (*M. Psoas Major* – TDR 062) and 12 cube rolls (*M. longissimus thoracis* – CUB045) from both countries totalling 48 high quality samples. The centre section of the TDR062 and the cranial end of the CUB045 were utilised. For the medium and lower quality levels (Choice, 4 Star, Select & 3 Star), 12 striploins (*M. longissimus lumborum* - STR045) and 12 cube rolls (*M. longissimus thoracis* – CUB045) were utilised (Table 1). The USDA graded beef came from 2 processing plants in the USA (Establishments 86R and 262). The MSA Graded beef came from 3 processing plants (Establishments 243, 8883 and 423). Product came from different production dates so some samples were frozen prior to consumer testing to ensure that the number of days ageing was equivalent between countries. The number of samples frozen prior to consumer testing was 24 USDA and 22 MSA graded samples (Table 1). Post-mortem ageing ranged between 27 and 34 days which would have minimal impact on consumer sensory scores (Table 1).

Table 1: Details of samples used across the four consumer sessions including processor, number samples (N), days aged prior to consumer testing and freezing status

Grade	Cut	Processor	N	Days aged	Frozen/thawed prior to consumer testing
USDA Prime	TDR062	A	12	30	Yes
USDA Prime	CUB045	A	12	34	No
USDA Choice	CUB045	A	12	32	No
USDA Choice	STR045	A	12	32	No
USDA Select	CUB045	A	12	32	No
USDA Select	STR045	B	12	30	Yes
5 Star MSA	TDR062	C	5	32	No
5 Star MSA	TDR062	D	3	30	Yes
5 Star MSA	TDR062	E	4	27	No
5 Star MSA	CUB045	C	5	32	No
5 Star MSA	CUB045	D	3	30	Yes
5 Star MSA	CUB045	E	4	34	No
4 Star MSA	CUB045	D	4	30	Yes
4 Star MSA	CUB045	E	8	34	No
4 Star MSA	STR045	D	4	30	Yes
4 Star MSA	STR045	E	8	34	No
3 Star MSA	CUB045	D	4	30	Yes
3 Star MSA	CUB045	E	8	34	No
3 Star MSA	STR045	D	4	30	Yes
3 Star MSA	STR045	E	8	34	No

3.2 Sample preparation

Each primal was trimmed of all external fat and epimysium (Figure 1). Steaks were sliced 25mm thick for consumer testing by pressing the primal tightly against the cutting jig when slicing perpendicular to the grain of the meat. The dimension of each sample was around 70mm x 40mm x 25mm (Figure

2) and a total of 5 samples were used from each primal. The five steaks from each primal were labelled into a single small vac bag of approximately 125mm x 300mm for later distribution into consumer session cooking round sheets.

Figure 1: Trimming of external fat on a striploin prior to slicing consumer samples

Figure 2: Slicing steaks on the beef cutting jig and 5 consumer samples

3.3 Consumer sensory evaluation

Meat eating evaluations were conducted using MSA protocol to ensure uniform testing. The standard MSA questionnaire and scoring sheets were translated to Japanese for the consumers. Briefly, meat samples were stored at 0°C prior to consumer testing, then grilled on Braun Clamshell Grill multigrill 7 (CG7040 De'Longhi Braun Household GmbH, Carl-Ulrich-Straße 4, 63263 Neu-Isenburg, Germany) grills set at 210°C for the bottom and 190°C for the top cast iron plate. For each cooking round, ten sample steaks were prepared. The steaks were cooked till reaching a "medium" degree of doneness (~68°C internal temperature), then rested for 3 minutes at room temperature. Subsequently, each steak was halved into two equal-sized rectangular pieces and served to two separate consumers.

A total of 240 adults, who usually consume beef at least once a month were recruited to participate in 4 sensory sessions. Each sensory session consisted of three groups of 20 untrained consumers with each 60 consumers evaluating a total of 42 samples. Each sample was evaluated by 10 different participants, with each consumer evaluating 7 samples. The initial sample (link sample), selected as an assumed mid-range eating quality (MSA 3 Star Striploin), was served as a standard reference for all participants. The following 6 test products were selected to represent expected different eating quality related to the different breed types and muscles with each consumer served one sample

from each product to ensure range. The order of serving for each consumer was controlled by a 6 x 6 Latin Square design, ensuring that each product was tasted in equal proportion before and after each other product and equally in serving orders 2 to 7. This protocol balanced out potential halo and order of serving effects. Consumers were instructed to use a 100 mm line scale to grade each sample based on tenderness (0 indicating not tender and 100 indicating very tender), juiciness (0 indicating not juicy and 100 indicating very juicy), flavour (0 indicating extreme dislike and 100 indicating extreme liking), and overall liking (0 indicating extreme dislike and 100 indicating extreme liking). Individual sensory scores provided by consumers were weighted as follows: 0.3 for tenderness, 0.1 for juiciness, 0.3 for flavour, and 0.3 for overall liking. These weighted scores were utilised to compute a meat quality score (MQ4) (Watson et al., 2008b).

3.4 Consumer demographics

There were 125 female consumers (52.1%) and 115 male consumers (47.9%) with a range of age demographics covered other than those aged 18 and 19 whom were represented by only 2 consumers (Figure 3). The largest group was 40 to 60 years at 38.8% (Figure 3).

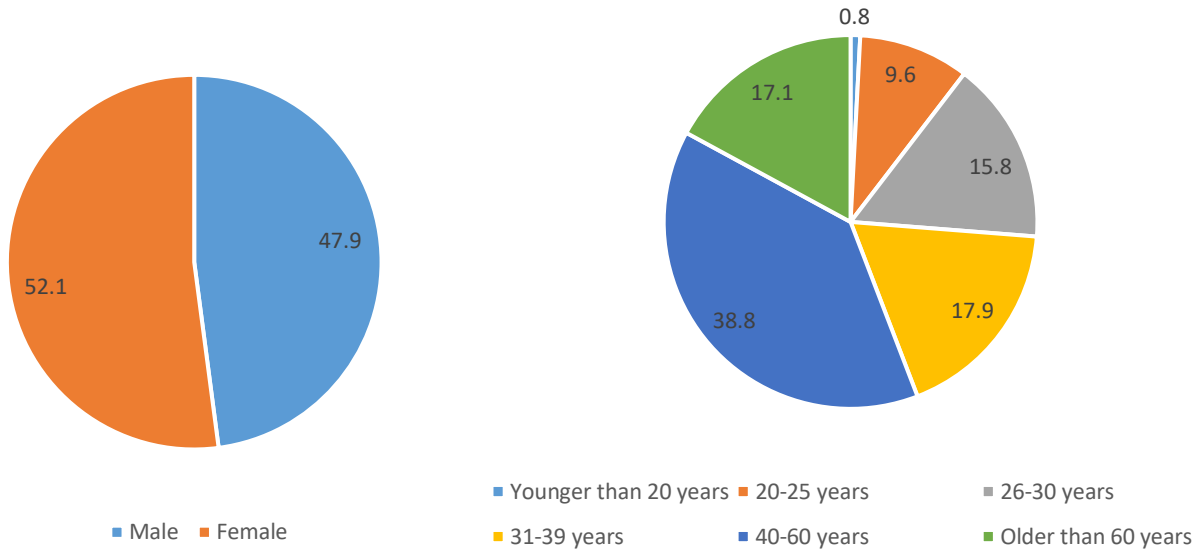

Figure 3a and b: The proportion of male and female consumers along with age demographics

Across the 240 consumers, there was a range of careers. The largest category represented was 35.8% for administration and the smallest was 2.1% for students (Figure 4). Figure 4 also shows that the degree of doneness reference for the 240 consumers aligned well with the internal cooking temperature used by the MSA protocol for grill. There was 34.2 and 33.8% of consumers that desired medium rare and medium steaks which was the target cook method. The smallest proportion (0.8%) likes their steak blue and only 2.9% well done (Figure 4).

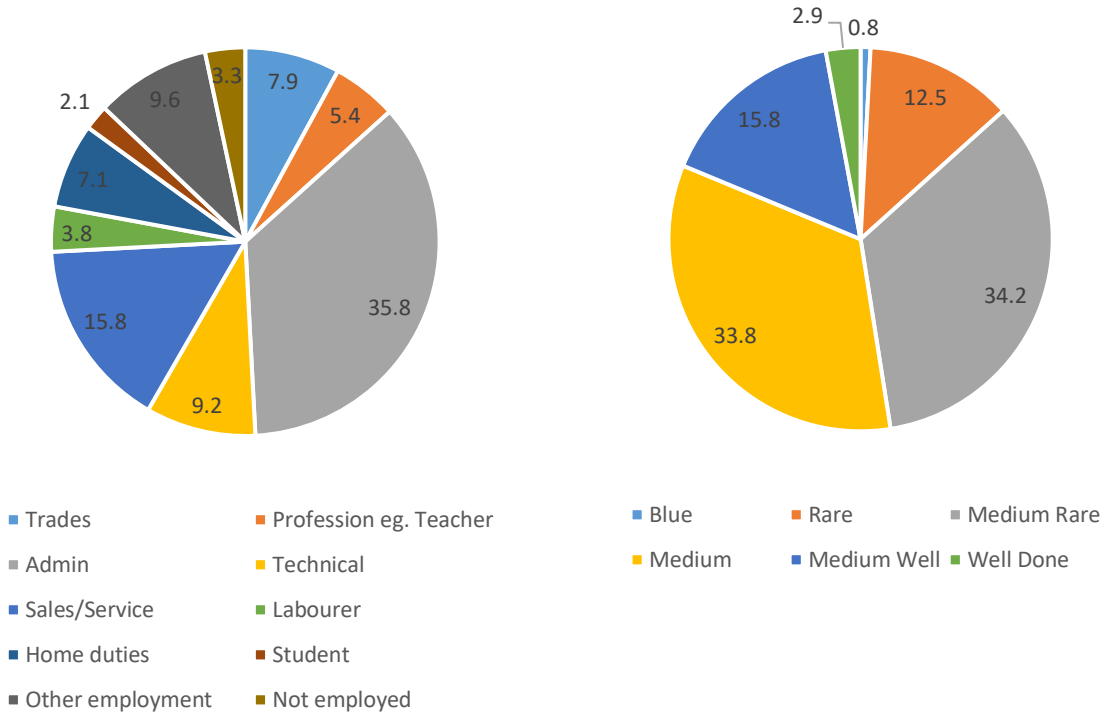

Figure 4a and b: The career categories of the 240 consumers along with their preference for degree of doneness for steak

The largest proportion of the 240 consumers (34.6%) ate beef weekly whilst 4.1% ate it 4 or more times a week and 12.1% ate it monthly (Figure 5a). The largest proportion of consumers (43.8%) agreed that they like red meat well enough and that's it's a regular part of their diet (Figure 5b).

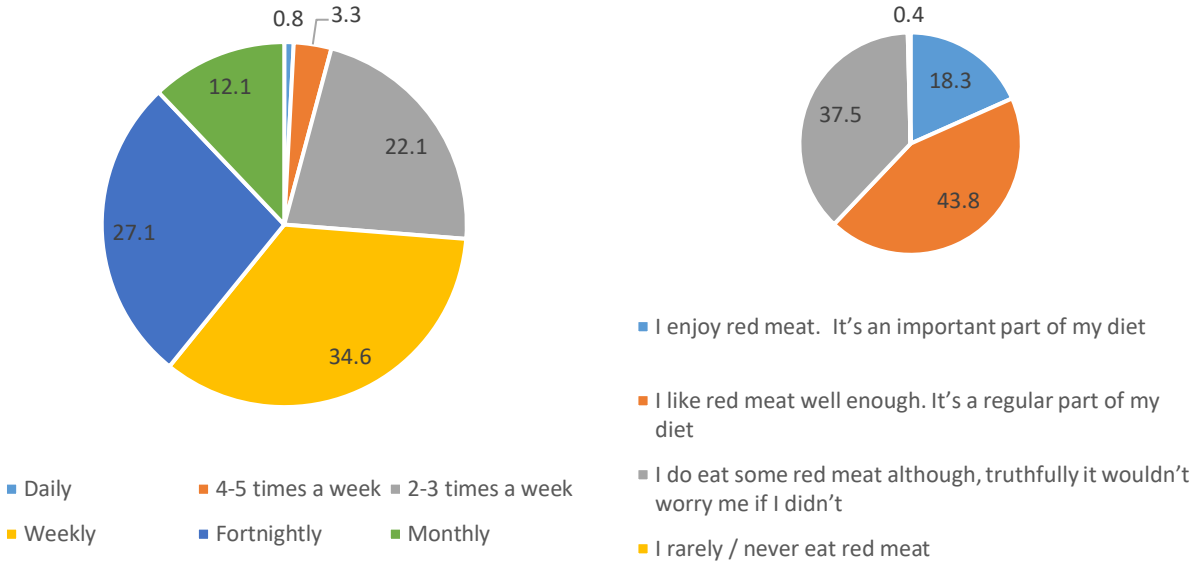

Figure 5a and b: The frequency of beef consumption by the 240 consumers and statements about the importance of red meat in the diet

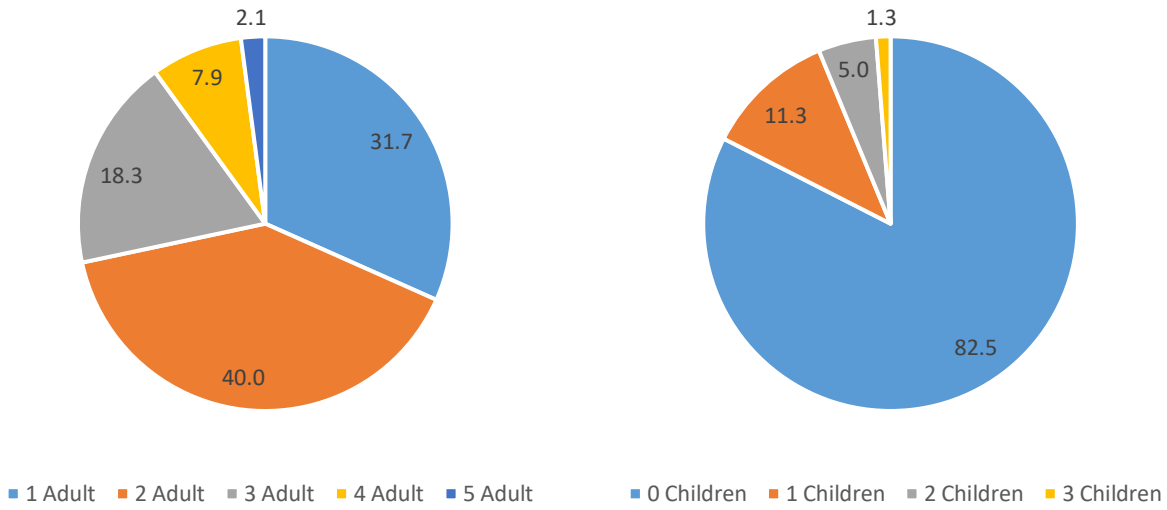

Figure 6a and b: The number of adults (18 years or older) and children (<18) in each household.

3.5 Statistical analysis

Data manipulation and summarization were performed in R (Team, 2024) using the dplyr and tidyr packages from the tidyverse (Wickham et al., 2019), while the gt package (Iannone, 2023) was employed to create the final summary table. Linear regression models were fitted using the lm() function, with cut, grade and their interaction as predictors for sensory attributes including consumer MQ4, tenderness, juiciness, flavour, and overall liking. Days aged, frozen status and feedtype (grass or grain) were also added as a covariate and fixed effect but were not significant (P>0.1). The significance of predictors was assessed using ANOVA and the interaction was removed as it was not significant.

The emmeans package (Lenth, 2023) was used to compute estimated marginal means (EMMs) for the sensory attributes, adjusted for the cut variable across different EQ grades. Pairwise comparisons were conducted to evaluate significant differences between the EQ grades.

Finally, the plot was created with the ggplot2 package, a part of the tidyverse (Wickham et al., 2019), to visualize the estimated marginal means with confidence intervals and EQ grades.

4. Results

4.1 Descriptive statistics

Table 2 below shows the mean and standard deviations of raw data from the 240 Japanese consumers for 144 samples consumed. The minimum and maximum vales are also displayed and show variability across all cut by quality combinations. The range of vales was smallest in MSA 5 star and USDA Prime product and increased as the quality decreased for all cuts and consumer parameters (Table 2).

Table 2. Raw means, standard deviations (in bracket), minimum and maximum values for each cut by each quality grade for tenderness, juiciness, flavour, overall liking and MQ4 scores.

CUT	MSA Five Star	MSA Four Star	MSA Three Star	USDA Prime	USDA Choice	USDA Select
			Tenderness			
CUB045	78.8 (6.4) 66.5-90.2	73.2 (13.0) 53.5-89.8	65.7 (14.7) 40.3-90.3	59.9 (10.4) 47.0-79.7	53.4 (11.7) 30.3-68.3	47.4 (14.6) 19.5-71.7
STR045		62.7 (11.2) 42.7-74.5	62.9 (12.4) 46.3-79.5		50.6 (12.9) 33.8-69.2	32.1 (11.2) 15.2-53.0
TDR062	86.7 (7.1) 75.0-98.5			87.4 (6.2) 72.8-93.0		
			Juiciness			
CUB045	80.2 (8.3) 62.0-94.5	72.4 (12.4) 52.7-88.7	57.0 (11.7) 38.7-76.7	64.7 (11.3) 45.8-81.7	56.1 (10.2) 39.3-72.3	43.8 (13.1) 24.3-73.8
STR045		64.0 (8.5) 49.8-73.0	55.3 (13.4) 26.5-70.7		51.5 (10.9) 37.0-69.8	35.3 (11.5) 20.7-54.3
TDR062	77.0 (7.9) 64.2-85.7			66.6 (7.0) 57.8-82.2		
			Flavour			
CUB045	78.4 (7.7) 64.5-89.0	72.9 (7.7) 61.5-84.2	59.9 (10.9) 39.7-73.5	70.8 (6.9) 60.2-83.0	61.4 (8.3) 51.2-77.7	52.8 (9.2) 40.2-74.7
STR045		62.3 (5.2) 54.2-69.2	61.3 (7.0) 46.5-71.5		55.8 (8.0) 40.8-68.7	47.2 (9.8) 30.7-65.5
TDR062	74.1 (6.8) 63.5-85.0			72.0 (6.6) 59.7-82.5		
			Overall Liking			
CUB045	80.2 (6.3) 68.8-89.3	75.5 (8.6) 63.0-86.5	61.8 (10.5) 42.3-76.0	66.8 (8.8) 54.7-83.2	60.2 (9.9) 42.2-77.3	50.9 (11.2) 26.5-71.8
STR045		63.6 (7.1) 53.7-77.2	61.1 (9.0) 45.7-74.0		55.0 (10.9) 39.7-71.3	39.4 (10.6) 23.5-57.8
TDR062	79.8 (6.5) 67.8-90.2			75.0 (6.1) 66.8-84.2		
			MQ4			
CUB045	78.9 (6.0) 66.8-88.4	73.2 (9.4) 59.8-86.1	61.8 (10.7) 42.2-77.5	65.5 (7.5) 56.9-79.8	58.1 (9.1) 43.2-74.7	49.6 (10.7) 29.5-71.2
STR045		62.3 (7.1) 50.9-72.1	60.9 (8.6) 45.9-74.5		54.7 (10.0) 40.8-67.4	39.3 (10.1) 24.6-56.5
TDR062	78.9 (6.4) 69.3-89.0			76.2 (5.3) 68.8-84.1		
			Satisfaction			
CUB045	3.9 (0.3) 3.3-4.3	3.7 (0.3) 3.2-4.2	3.3 (0.2) 3.0-3.7	3.4 (0.3) 3.0-4.0	3.1 (0.3) 2.7-3.7	2.9 (0.3) 2.2-3.3
STR045		3.3 (0.3) 2.7-3.7	3.2 (0.3) 2.7-3.5		3.1 (0.3) 2.5-3.5	2.6 (0.2) 2.2-3.0
TDR062	4.0 (0.4) 3.5-4.7			3.8 (0.2) 3.5-4.2		

4.2 Meat Quality (MQ4)

The fixed effects for cut and grade were very significant (P<0.0001) for all sensory traits (Table 3), however the interaction between traits was not significant. This indicates that the effect of cuts was the same across eating quality grades (Table 3).

Table 3. Numerator and denominator degrees of freedom (NDF, DDF), F-value and P-values for cut and grade from linear models for the different eating quality traits MQ4, tenderness, juiciness, flavour and overall liking.

Traits	Cut				Grade			
	NDF	DDF	F-value	P-value	NDF	DDF	F-value	P-value
MQ4	2	136	56.90	***	5	136	25.44	***
Tenderness	2	136	71.04	***	5	136	20.61	***
Juiciness	2	136	31.78	***	5	136	27.60	***
Flavour	2	136	36.93	***	5	136	20.45	***
Overall Liking	2	136	51.65	***	5	136	25.14	***

Signif. codes: 0 '***' , 0.001 '**' , 0.01 '*', 0.05 '.', 0.1 ' ' 1

When the data for the 2 cuts in each quality grade were combined, the MQ4 score was highest for MSA 5 Star at 78.89 points and lowest for USDA Select at 44.45 points (P<0.01, Figure 7). The MQ4 scores for USDA Prime (70.89) and MSA 4 Star (67.78) did not significantly differ from each other. MSA 4 Star and MSA 3 Star did also not differ from each other significantly (P>0.05) and MSA 3 Star did also not differ from USDA Choice (Figure 7). When cuts were combined, all 3 USDA grades did differ significantly from each other (Figure 7).

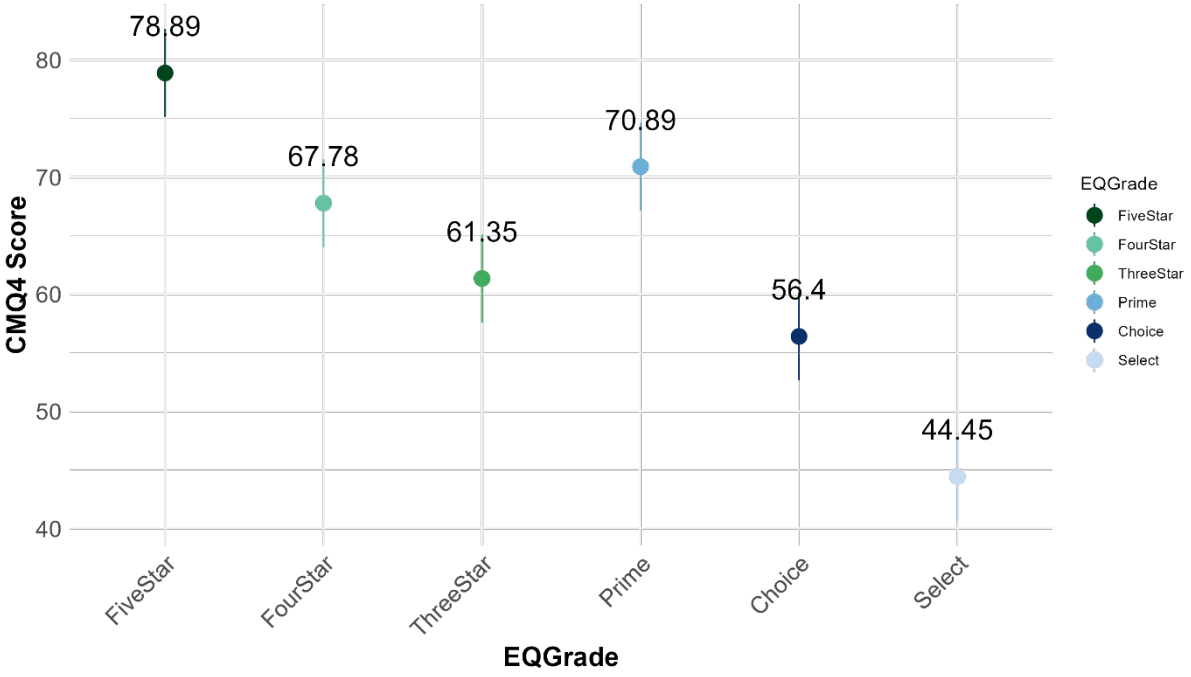

Figure 7. Estimated marginal means of Consumer MQ4 scores by eating quality grade with 95% confidence intervals.

When cut and quality grade were both included in the model, there were significant differences between cuts and quality grades. Both the CUB045 and TDR062 MSA 5 Star scored the same as each other at 78.89 and 78.88 points confirming that the MSA prediction model can predict quality grades independent of cut (Figure 8) with both these cuts scoring >76 points which is the minimum boundary for MSA 5 Star. The MSA 5 Star cuts were not significantly higher than the USDA Prime TDR062 and the MSA 4 Star CUB045 which scored 76.24 and 73.23 points respectively (P>0.05, Figure 8). The USDA Prime CUB045 was 10.7 points lower than the USDA Prime TRD062 but did not significantly differ (P>0.05, Figure 8). USDA Select STR045 scored signifcantly lower than all other cuts at 39.3 points (P<0.05) other than the USDA Select CUB045 which scored 49.6 points (P>0.05, Figure 8). The USDA Select CUB045 did not significantly differ from the Choice STR045, Choice CUB045 or the MSA 3 Star STR045 which scored 54.7, 58.1 and 60.9 points respectively (P>0.05, Figure 8). There was an 11.9 point discrepency between the MSA 4 Star CUB045 and STR045 however this was not significant. The MSA 3 Star CUB045 and STR045 scored very similarly at 61.8 and 60.9 points which is within upper end of the 3 Star range of 46 to 64 points (Figure 8).

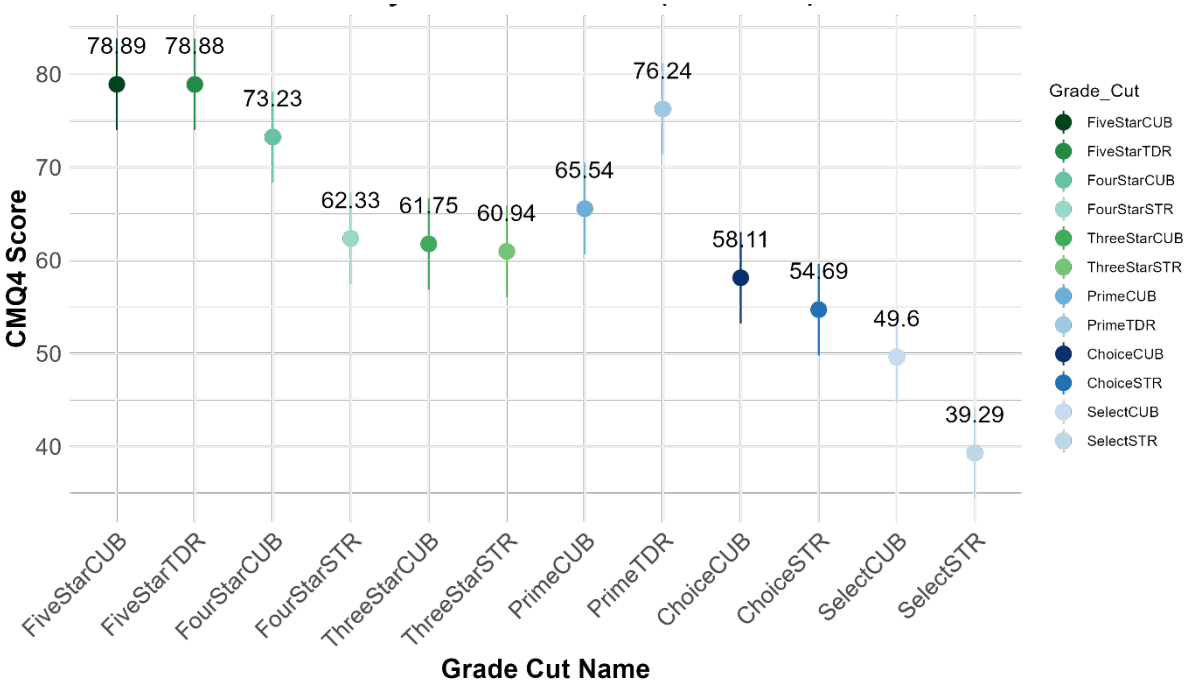

Figure 8. Estimated marginal means of Consumer MQ4 scores by eating quality grade and cut with 95% confidence intervals.

4.3 Tenderness

For tenderness as rated by untrained consumers, the MSA 5 Star scored the highest at 82.8, which did not differ significantly from the USDA Prime, which scored 73.7 (P>0.05, Figure 9). The USDA Prime did also not differ significantly from the MSA 4 Star and MSA 3 Star at 67.9 and 64.3 points respectively for tenderness (P>0.05, Figure 9). USDA Select scored lowest of all quality grades for tenderness at 39.7 points (P<0.05, Figure 9) and USDA Choice was higher than Select but lower than all other quality grades at 52 points (P<0.05, Figure 8). Interestingly the scores for tenderness for MSA 5 Star, USDA Prime and MSA 3 Star were 3.87, 2.78 and 2.97 points higher than the combined MQ4 scores respectively. However, the tenderness scores for USDA Choice and Select were 4.42 and 4.72 points lower than the MQ4 score respectively.

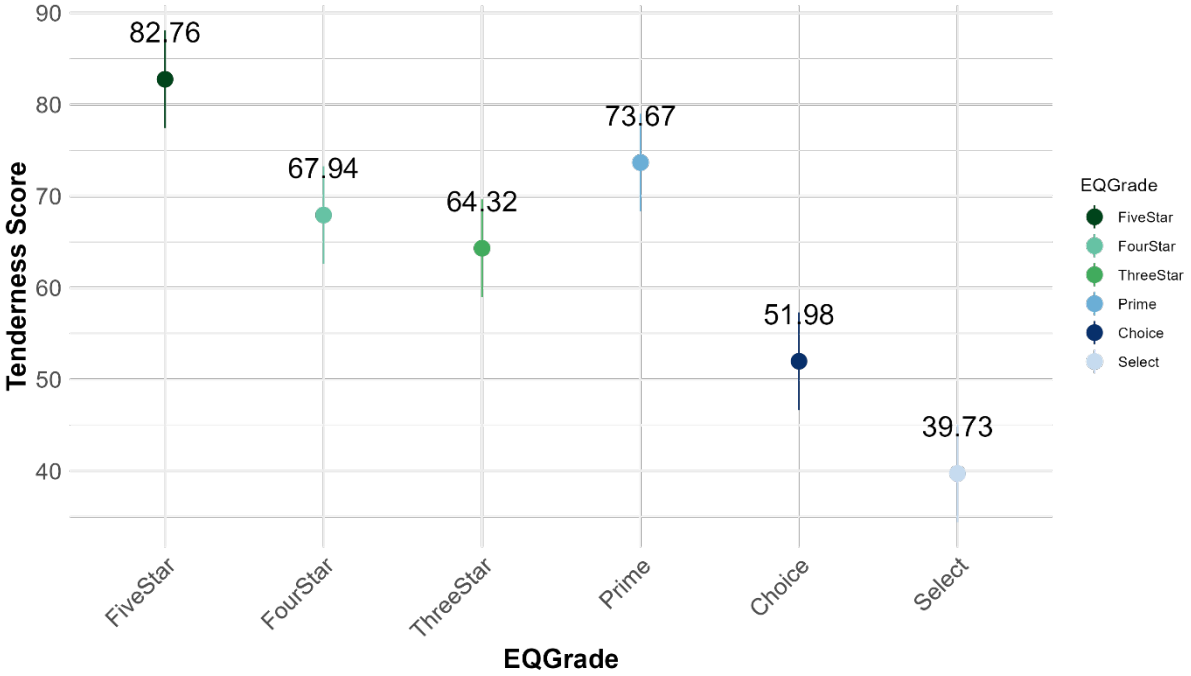

Figure 9. Estimated marginal means of tenderness scores by eating quality grade with 95% confidence intervals.

Tenderness did not differ within the two MSA 5 Star cuts, two 4 Star cuts or two 3 Star cuts (P>0.05, Figure 10). The USDA Prime TDR062 was 27.5 points higher for tenderness than the USDA Prime CUB045 at 87.4 points (P<0.001, Figure 10). Tenderness did not differ within the two USDA Choice cuts or the two USDA Select cuts (P>0.05, Figure 10) even though the select differed by 15.29 points.

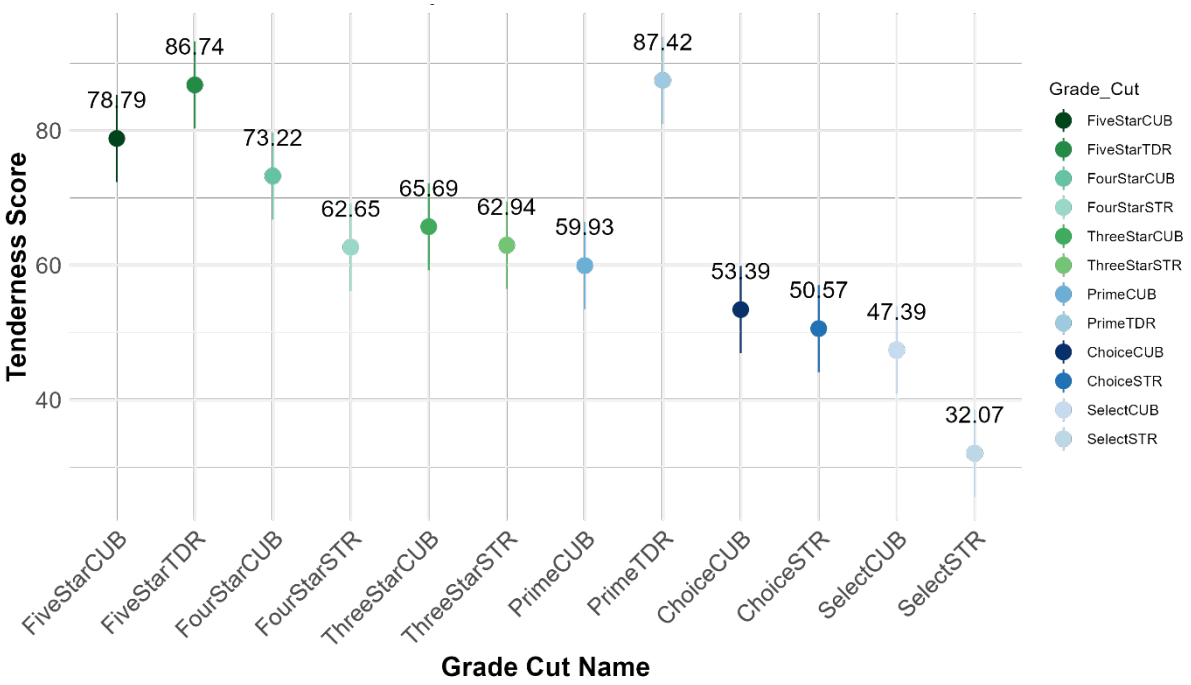

Figure 10. Estimated marginal means of tenderness scores by eating quality grade and cut with 95% confidence intervals.

4.4 Juiciness

The 3 MSA quality grades varied significantly for juiciness (P<0.05, Table 3, Figure 11) and were very similar scores to the MQ4 for each quality grade other than 3 star which was numerically lower by 5.61 points. The MSA 5 Star score for juiciness was significantly higher than the juiciness score of 65.7 for the USDA Prime by 12.9 points (P<0.05, Figure 11), but USDA Prime juiciness score did not differ from MSA 4 Star juiciness score of 68.2 (P>0.05, Figure 11). Likewise, there was similarity in the juiciness scores of the USDA Choice and MSA 3 Star quality of 53.8 and 56.1 respectively (P>0.05, Figure 11). USDA Select scored the lowest of all quality grades for juiciness at 39.5 points (P<0.01, Figure 11).

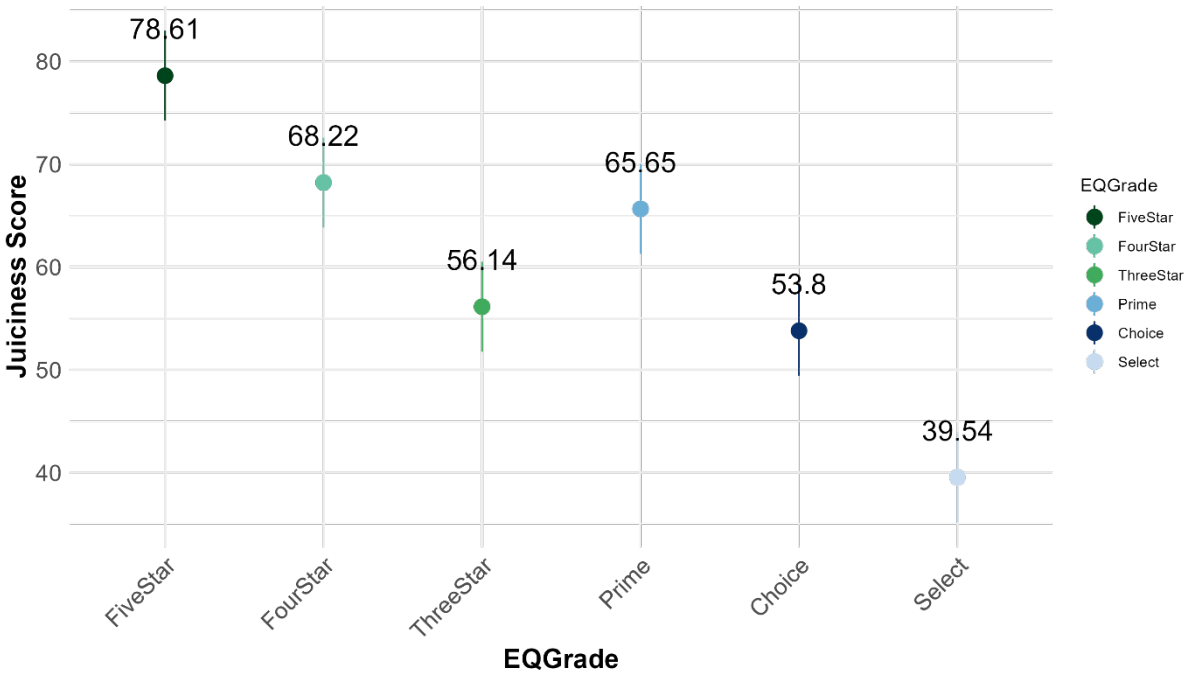

Figure 11. Estimated marginal means of juiciness scores by eating quality grade with 95% confidence intervals.

There was a good spread of juiciness scores across the cuts with the MSA 5 Star CUB045 scoring the highest juiciness score of 80.2 points and USDA Select STR045 scoring the lowest at 35.3 points (Figure 12).

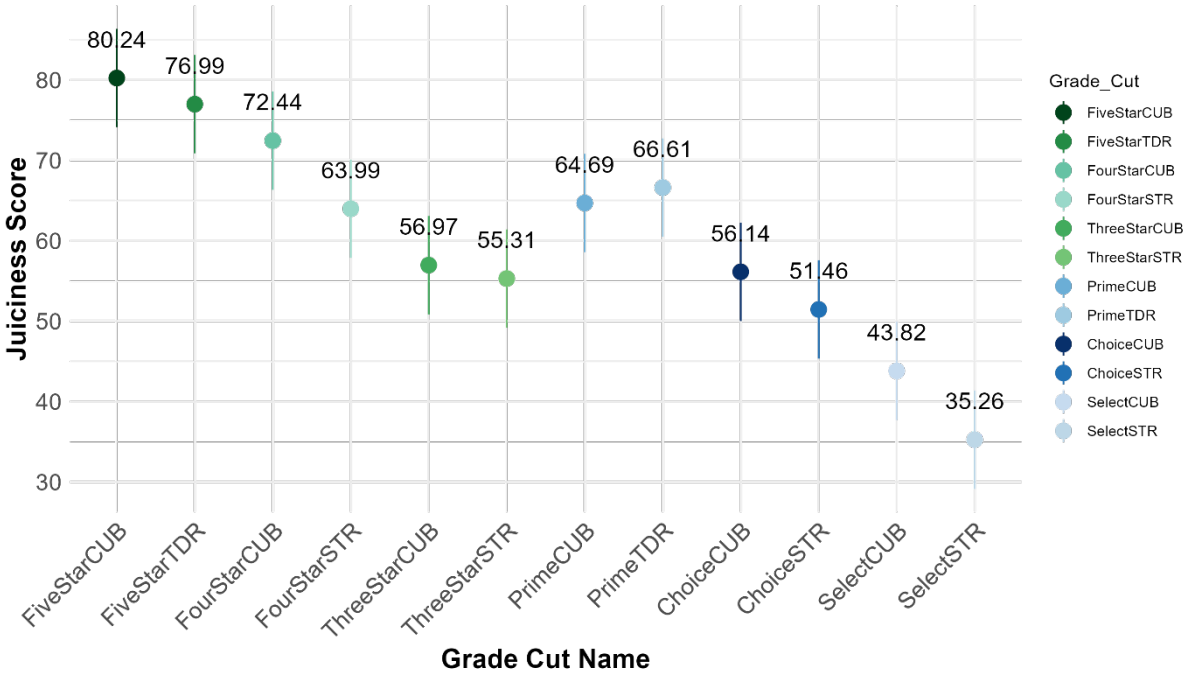

Figure 12. Estimated marginal means of juiciness scores by eating quality grade and cut with 95% confidence intervals.

4.5 Flavour

The scores for the liking of flavour and MQ4 scores were similar for all MSA quality grades and USDA Prime and Choice grades (Figure 13 and Figure 7). The largest discrepancy between MQ4 score and flavour was seen in the USDA Select cuts which scored 10.66 points higher for flavour (49.97) than MQ4 score.

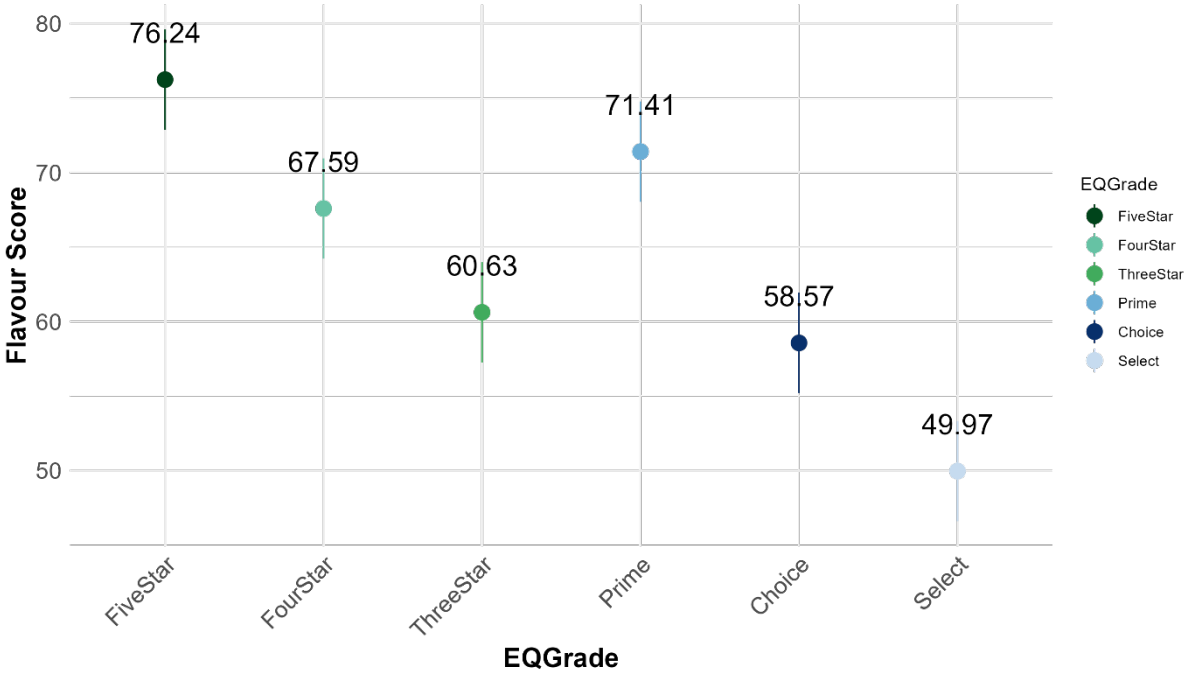

Figure 13. Estimated marginal means of flavour scores by eating quality grade with 95% confidence intervals.

The flavour scores for MSA 5 Star CUB045 was highest overall at 78.39 points but it was not significantly higher than the 5 Star TDR062, 4 Star CUB045, USDA Prime CUB045 and TDR062 at 74.1, 72.87, 70.85 and 71.97 points respectively (P>0.05, Figure 14). The USDA Select STR045 scored the lowest for flavour at 47.15 but it did not differ significantly from the USDA Select CUB045 and Choice STR045 which scored 52.78 and 55.76 points (Figure 14).

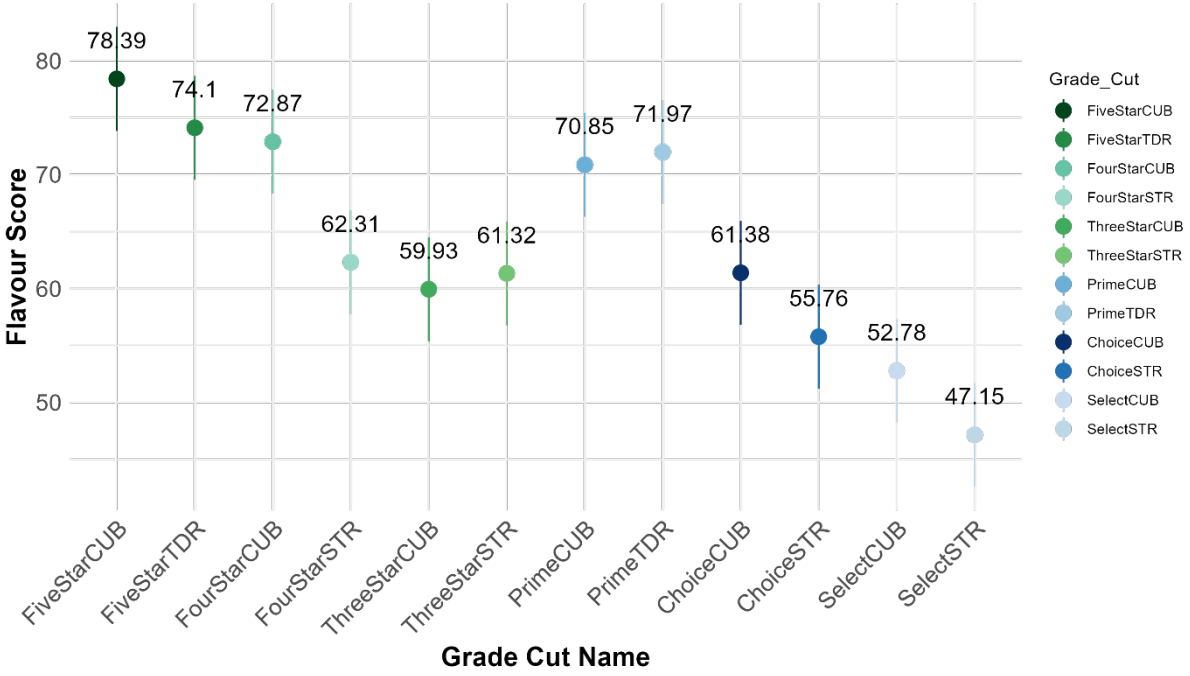

Figure 14. Estimated marginal means of flavour scores by eating quality grade and cut with 95% confidence intervals.

4.6 Overall Liking

The 3 MSA quality grades varied significantly for overall liking (P<0.05, Table 3, Figure 15) and were very similar scores to the MQ4 for each quality grade. At 80 points, the MSA 5 Star score for overall liking was significantly higher than the overall liking score of 70.9 for the USDA Prime by 9.1 points (P<0.05, Figure 15), but USDA Prime overall liking score did not differ from MSA 4 Star overall liking score of 69.5 (P>0.05, Figure 15). Likewise, there was similarity in the overall liking scores of the USDA Choice and MSA 3 Star quality of 57.6 and 61.4, respectively (P>0.05, Figure 15). USDA Select scored the lowest of all quality grades for overall liking at 39.9 points (P<0.01, Figure 15).

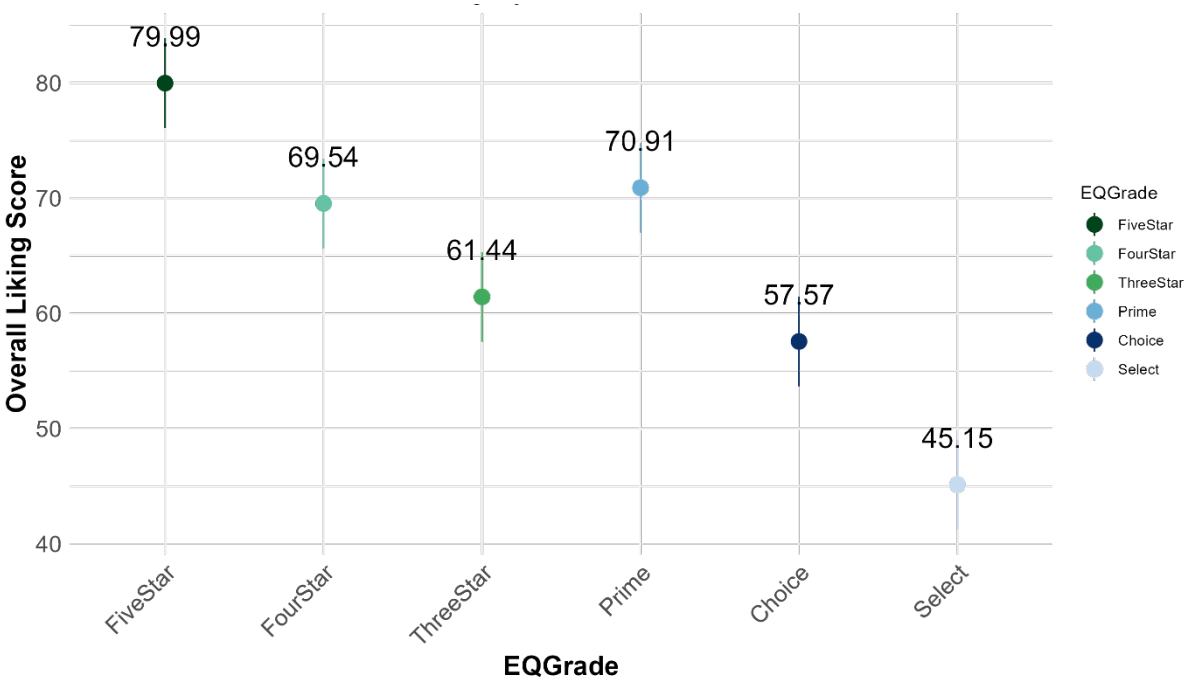

Figure 15. Estimated marginal means of overall liking scores by eating quality grade with 95% confidence intervals.

The overall liking scores for MSA 5 Star CUB045 was highest overall at 80.21 points but it was not significantly higher than the 5 Star TDR062, 4 Star CUB045 and USDA Prime TDR062 at 79.76, 75.5 and 75.01 points respectively (P>0.05, Figure 16). The USDA Select STR045 scored the lowest for over liking at 39.42 but it did not differ significantly from the USDA Select CUB045 which scored 50.88 points (Figure 14).

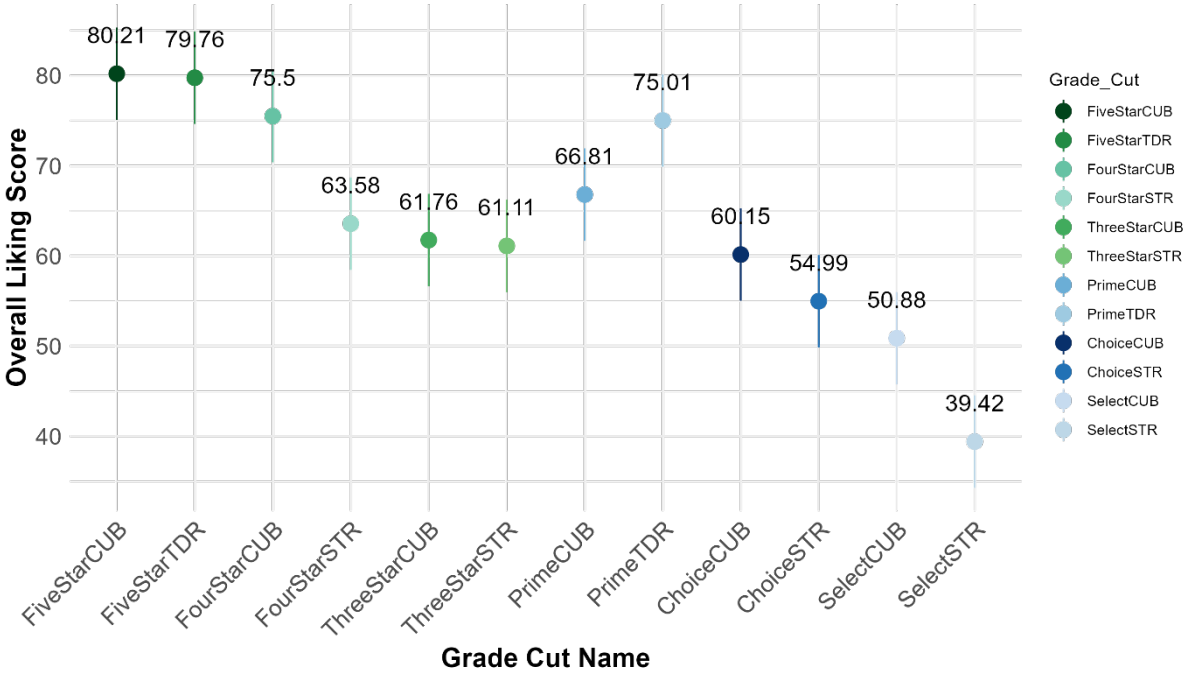

Figure 16. Estimated marginal means of overall liking scores by eating quality grade and cut with 95% confidence intervals.

4.7 Willingness to pay

The 240 Japanese consumers were willing to pay 383 Yen per 100g of beef for MSA 3 Star "Good everyday quality" beef (Figure 17). This price for the percentage (orange line) in Figure 17 was deemed to be 100%. For 5 Star "Premium Quality" beef, Japanese consumers were willing to pay 138% more or 911 Yen per 100g for beef (Figure 17). For MSA 4 Star "Better than Everyday Quality" beef, Japanese consumers were willing to pay 61% more than 3 Star Beef at 615 Yen per 100g (Figure 17). On the flipside, Japanese consumers were only willing to pay 49% of the price for unsatisfactory beef or 186 Yen per 100g (Figure 17).

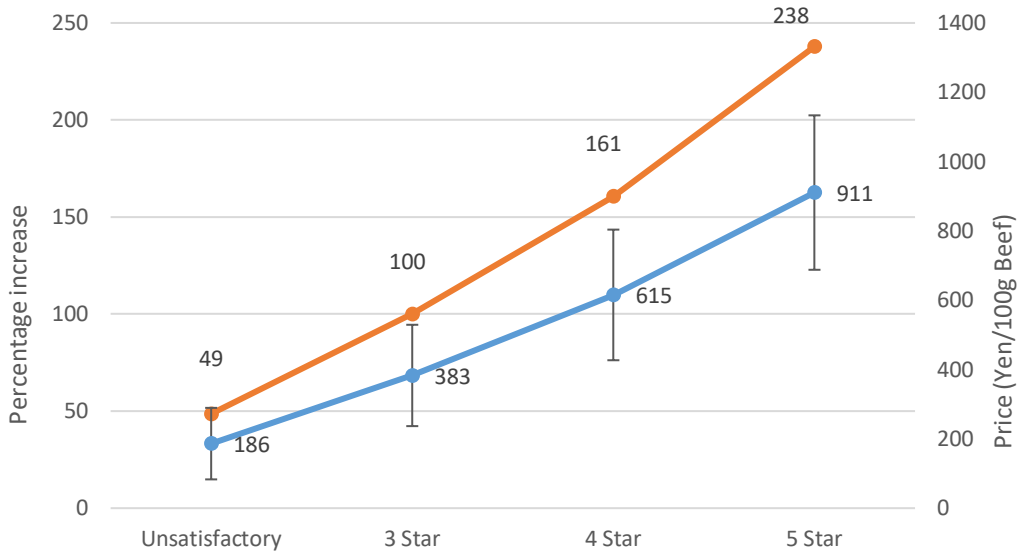

Figure 17. Japanese consumers' willingness to pay for different MSA quality grades in Japanese Yen per 100g (blue line) and the percentage variation (orange line) compared to the willingness to pay for 3 star "good everyday" graded beef.

5. Conclusions

The purpose of the project was to demonstrate, through consumer testing using Japanese consumers, that the more complex MSA beef grading system delivers a higher standard of quality grading than the USDA grading system, which has been supported by the consistency of the results. The MSA quality grading system delivered the highest MQ4 score for 5 Star "Premium Quality" beef which was higher than all other quality grades when tenderloin and cube roll scores were combined. USDA Prime had an equal MQ4 score as MSA 4 Star "Better than Everyday Quality" beef. MSA 3 Star "Good Everyday Quality" beef ranked equal to USDA Choice, while USDA Select quality beef had significantly lower MQ4 scores than all other quality grades. The same cuts, post-mortem ageing periods and cook method were utilised to minimise the impact of non-biological factors impacting on consumer sensory scores hence the variation between quality grades is due to biological variation. Interestingly the MSA prediction model for beef quality delivered similar scores for the 2 cuts utilised in the 5 Star and 3 Star quality grades, meanwhile there was always variation in MQ4 score between cuts of the same grade for USDA graded primals. This indicates that the cut by cook prediction model of MSA delivers greater precision of product quality to the consumer than the

USDA grading system. The variation between cuts and lower scores of the USDA quality grades may be partially due to the USDA system not taking key factors which impact meat quality into consideration like *Bos indicus* content, HGP status and beta agonist usage which all negatively impact quality especially the *M. longissimus thoracis et lumborum*. A carcass grading system which only accounts for marbling and physiological maturity or dentition would likely only describe 10 to 20% of variation in quality at best, hence why there is still variability seen between cuts within the same USDA grade. The MSA system does not account for feed type as nutrition has biological impacts through other measured traits like marbling, carcass weight, fatness and physiological maturity at market weight. The data from this experiment shows that it is not necessary to include feed type or finishing system in the eating quality prediction model as the model is already accurate utilising the input variables presently used.

5.1 Key findings

- MQ4 score of MSA 5 Star beef scored the highest – higher than USDA Prime using the same 2 cuts – tenderloin and cube roll
- USDA Select Cube Roll and Striploin scored the lowest MQ4 scores
- USDA Prime had an equal MQ4 score with MSA 4 Star beef
- MSA 3 Star and USDA Choice had similar MQ4 scores
- Carcass based grading systems which only account for marbling and physiological maturity do not deliver cuts with a guaranteed quality to consumers as they do not account for all the factors that influence eating quality like *Bos indicus* content, HGP status and beta agonist usage which all negatively impact quality.
- The results clearly show that a cut based system delivers the same quality into MSA quality grades accurately regardless of cut ensuring that consumers do not need intimate knowledge of muscle and anatomy of a carcass to purchase the correct beef for their meal.
- Feed type did not impact MSA prediction outcomes for product quality.
- Willingness to pay for MSA 5 Star and 4 Star product was 138% and 61% higher than 3 Star quality while consumers were willing to pay 49% of 3 Star price for unsatisfactory product.
- Consistency in quality between cuts can only be guaranteed by MSA.

5.2 Benefits to industry

This research provides insight and evidence for Australian beef processors and brand owners to compare MSA 3, 4 and 5 Star quality cuts to USDA grade Prime, Choice and Select. This is very useful when marketing beef in international markets where both Australia and the USA are key exporters like Japan, Korea and many nations around the world.

6. Future research and recommendations

The project insights should be turned into fact sheets or visualised in a way to assist international marketing teams from Australian processors and non-packer exporters to assist with the sales of MSA graded beef into markets which are dominated by USDA graded product or where the purchasers have knowledge of USDA grades. The results allow for a direct comparison on a product and quality grade basis so that they can purchase beef from Australia that meets their needs.

Future projects could revolve around a comparison of similar MSA graded lamb or beef products in other important international markets. Whilst this project aimed to replicate a global consumer, further sensory testing using the MSA protocol may be used to assist marketing efforts such as demonstrating the consistency of MSA graded non-Grainfed product, in partnership with Australian exporters. Consumers from different countries will have give slightly different absolute scores but the difference between grades typically stays constant (Nguyen et al., 2024) when using the MSA protocol on untrained consumers.

It is also advised that a low end MSA 3 Star quality grade gets created to match a similar quality level of USDA Select. The MSA 3 Star product that was consumer tested as part of this project was high end 3 Star scoring >55 points and was comparable to USDA Choice. The low end 3 Star could be Select quality, >55 points could become 4 Star Good everyday quality, ≥64 points could become 5 Star Better than Everyday Quality and ≥76 MQ4 score points could become 6 Star beef as it scored higher than USDA Prime and is rare and of minimal quantity. This would give that product a pedestal of its own as deserved.

7. References

Iannone, R., Cheng, J., & Schloerke, B. 2023. gt: Easily Create Presentation-Ready Display Tables (R package version 0.9.0).

Lean, I. J., H. M. Golder, N. M. Lees, P. McGilchrist, and J. E. Santos. 2018. Effects of hormonal growth promotants on beef quality: a meta-analysis. J. Anim. Sci. 96(7):2675-2697.

Lean, I. J., J. M. Thompson, and F. R. Dunshea. 2014. A meta-analysis of zilpaterol and ractopamine effects on feedlot performance, carcass traits and shear strength of meat in cattle. PloS one 9(12):e115904.

Lenth, R. V. 2023. emmeans: Estimated Marginal Means, aka Least-Squares Means (R package version 1.8.9). CRAN.

McGilchrist, P., R. J. Polkinghorne, A. J. Ball, and J. M. Thompson. 2019. The Meat Standards Australia Index indicates beef carcass quality. animal 13(8):1750-1757. doi: 10.1017/S1751731118003713

Nguyen, D. V., O. C. Nguyen, and A. E. O. Malau-Aduli. 2021. Main regulatory factors of marbling level in beef cattle. Veterinary and Animal Science 14:100219. doi: https://doi.org/10.1016/j.vas.2021.100219

Nguyen, D. V., R. Polkinghorne, and P. McGilchrist. 2024. Sensory evaluation of high-marbling beef cuts by Australian and Middle Eastern consumers. Food Science of Animal Resources

Packer, D., G. Geesink, J. Thompson, R. Polkinghorne, A. Ball, and P. McGilchrist. 2021a. The impact of different Hormonal Growth Promotants (HGP) on desmin degradation and collagen content of various muscles from pasture and feedlot finished steer carcasses. Meat Science 182:108615.

Packer, D., P. McGilchrist, R. Polkinghorne, A. Ball, and J. Thompson. 2021b. Does a single adjustment in the meat standards Australia beef grading model cater for different hormonal growth promotant formulations? Animal 15(5):100196.

Packer, D. T., G. H. Geesink, R. Polkinghorne, J. M. Thompson, A. J. Ball, and P. McGilchrist. 2018. The impact of oestradiol only hormone growth promotants (HGPs) on the eating quality of pasture finished steer carcasses. Meat Science 146:41-49. doi: 10.1016/j.meatsci.2018.06.038

Park, B. Y., I. H. Hwang, S. H. Cho, Y. M. Yoo, J. H. Kim, J. M. Lee, R. Polkinghorne, and J. M. Thompson. 2008. Effect of carcass suspension and cooking method on the palatability of three beef muscles as assessed by Korean and Australian consumers. Australian Journal of Experimental Agriculture 48(11):1396-1404. doi: Doi 10.1071/Ea07189

Polkinghorne, R. J., J. M. Thompson, R. Watson, A. Gee, and M. Porter. 2008. Evolution of the Meat Standards Australia (MSA) beef grading system. Australian Journal of Experimental Agriculture 48(11):1351-1359. doi: 10.1071/Ea07177

Smith, G., J. Tatum, and K. Belk. 2008. International perspective: characterisation of United States Department of Agriculture and Meat Standards Australia systems for assessing beef quality. Australian Journal of Experimental Agriculture 48(11):1465-1480.

Team, R. D. C. 2024. R: A language and environment for statistical computing. Published online 2020 Supplemental Information References No. 1. p 371-378. R Foundation for Statistical Computing, Vienna, Austria.

Thompson, J. 2002. Managing meat tenderness. Meat Science 62(3):295-308.

Thompson, J. M., D. Perry, B. Daly, G. E. Gardner, D. J. Johnston, and D. W. Pethick. 2006. Genetic and environmental effects on the muscle structure response post-mortem. Meat Science 74(1):59-65.

Watson, R., A. Gee, R. Polkinghorne, and M. Porter. 2008a. Consumer assessment of eating quality - development of protocols for Meat Standards Australia (MSA) testing. Australian Journal of Experimental Agriculture 48(11):1360-1367. doi: Doi 10.1071/Ea07176

Watson, R., A. Gee, R. Polkinghorne, and M. Porter. 2008b. Consumer assessment of eating quality development of protocols for Meat Standards Australia (MSA) testing. Aust J Exp Agric 48(11):1360-1367. doi: https://doi.org/10.1071/EA07176

Watson, R., R. Polkinghorne, and J. M. Thompson. 2008c. Development of the Meat Standards Australia (MSA) prediction model for beef palatability. Australian Journal of Experimental Agriculture 48(11):1368-1379. doi: https://doi.org/10.1071/EA07184

Watson, R., R. J. Polkinghorne, and J. M. Thompson. 2008d. Development of the Meat Standards Australia (MSA) prediction model for beef palatability. Australian Journal of Experimental Agriculture 48(11):1368-1379. doi: Doi 10.1071/Ea07184

Wickham, H., M. Averick, J. Bryan, W. Chang, L. D. McGowan, R. François, G. Grolemund, A. Hayes, Henry,, H. L., K. J., P. M., M. T. L., B. E., M. S. M., O. K., R. J., S. D., S. D. P., T. V., V. K., W. D., W. C., K., and H. Yutani. 2019. Welcome to the tidyverse.

8. Appendix

Estimated Marginal Means- CMQ4

Table 4. Estimated marginal means of CMQ4 for different EQgrade adjusted for cut

EQ Grade	EMMeans	SE	df	Lower.CL	Upper.CL	Significance
FiveStar	78.9	1.9	138	73.8	83.9	e
FourStar	67.8	1.9	138	62.7	72.8	cd
ThreeStar	61.3	1.9	138	56.3	66.4	bc
Prime	70.9	1.9	138	65.8	76.0	d
Choice	56.4	1.9	138	51.3	61.5	b
Select	44.4	1.9	138	39.4	49.5	a

Table 5. Estimated marginal means of CMQ4 for different EQgrade by cut

EQ Grade by cut	EMMeans	SE	df	Lower.CL	Upper.CL	Significance
FiveStarCUB	78.9	2.49	132	71.7	86.1	f
FiveStarTDR	78.9	2.49	132	71.6	86.1	f
FourStarCUB	73.2	2.49	132	66.0	80.5	def
FourStarSTR	62.3	2.49	132	55.1	69.6	cd
ThreeStarCUB	61.8	2.49	132	54.5	69.0	cd
ThreeStarSTR	60.9	2.49	132	53.7	68.2	bc
PrimeCUB	65.5	2.49	132	58.3	72.8	cde
PrimeTDR	76.2	2.49	132	69.0	83.5	ef
ChoiceCUB	58.1	2.49	132	50.9	65.3	bc
ChoiceSTR	54.7	2.49	132	47.5	61.9	bc
SelectCUB	49.6	2.49	132	42.4	56.8	ab
SelectSTR	39.3	2.49	132	32.1	46.8	a

Estimated Marginal Means- Tenderness

Table 6. Estimated marginal means of Tenderness for different EQgrade adjusted for cut

EQ Grade	EMMeans	SE	df	Lower.CL	Upper.CL	Significance
FiveStar	82.8	2.69	138	75.6	90.0	d
FourStar	67.9	2.69	138	60.7	75.1	c
ThreeStar	64.3	2.69	138	57.1	71.5	c
Prime	73.7	2.69	138	66.5	80.9	cd
Choice	52.0	2.69	138	44.8	59.2	b
Select	39.7	2.69	138	32.5	46.9	a

Table 7. Estimated marginal means of tenderness for different EQgrade by cut

EQ Grade by cut	EMMeans	SE	df	Lower.CL	Upper.CL	Significance
FiveStarCUB	78.8	3.27	132	69.3	88.3	ef
FiveStarTDR	86.7	3.27	132	77.2	96.3	f
FourStarCUB	73.2	3.27	132	63.7	82.7	def
FourStarSTR	62.7	3.27	132	53.1	72.2	bcd
ThreeStarCUB	65.7	3.27	132	56.2	75.2	cde

ThreeStarSTR	62.9	3.27	132	53.4	72.5	cd
PrimeCUB	59.9	3.27	132	50.4	69.4	bcd
PrimeTDR	87.4	3.27	132	77.9	96.9	f
ChoiceCUB	53.4	3.27	132	43.9	62.9	bc
ChoiceSTR	50.6	3.27	132	41.1	60.1	bc
SelectCUB	47.4	3.27	132	37.9	56.9	ab
SelectSTR	32.1	3.27	132	22.6	41.6	a

Estimated Marginal Means- Juiciness

Table 8. Estimated marginal means of juiciness for different EQgrade adjusted for cut

EQ Grade	EMMeans	SE	df	Lower.CL	Upper.CL	Significance
FiveStar	78.6	2.21	138	72.7	84.5	d
FourStar	68.2	2.21	138	62.3	74.1	c
ThreeStar	56.1	2.21	138	50.2	62.0	b
Prime	65.7	2.21	138	59.7	71.6	c
Choice	53.8	2.21	138	47.9	59.7	b
Select	39.5	2.21	138	33.6	45.5	a

Table 9. Estimated marginal means of juiciness for different EQgrade by cut

EQ Grade by cut	EMMeans	SE	df	Lower.CL	Upper.CL	Significance
FiveStarCUB	80.2	3.09	132	71.2	89.2	f
FiveStarTDR	77.0	3.09	132	68.0	86.0	ef
FourStarCUB	72.4	3.09	132	63.5	81.4	ef
FourStarSTR	64.0	3.09	132	55.0	73.0	cde
ThreeStarCUB	57.0	3.09	132	48.0	66.0	bcd
ThreeStarSTR	55.3	3.09	132	46.3	64.3	bcd
PrimeCUB	64.7	3.09	132	55.7	73.7	cde
PrimeTDR	66.6	3.09	132	57.6	75.6	def
ChoiceCUB	56.1	3.09	132	47.2	65.1	bcd
ChoiceSTR	51.5	3.09	132	42.5	60.4	bc
SelectCUB	43.8	3.09	132	34.8	52.8	ab
SelectSTR	35.3	3.09	132	26.3	44.3	a

Estimated Marginal Means- Flavour

Table 10. Estimated marginal means of juiciness for different EQgrade adjusted for cut

EQ Grade	EMMeans	SE	df	Lower.CL	Upper.CL	Significance
FiveStar	76.2	1.7	138	71.7	80.8	d
FourStar	67.6	1.7	138	63.0	72.1	c
ThreeStar	60.6	1.7	138	56.1	65.2	b
Prime	71.4	1.7	138	66.9	76.0	cd
Choice	58.6	1.7	138	54.0	63.1	b
Select	50.0	1.7	138	45.4	54.5	a

Table 11. Estimated marginal means of juiciness for different EQgrade by cut

EQ Grade by cut	EMMeans	SE	df	Lower.CL	Upper.CL	Significance
FiveStarCUB	78.4	2.31	132	71.7	85.1	e
FiveStarTDR	74.1	2.31	132	67.4	80.8	e
FourStarCUB	72.9	2.31	132	66.2	79.6	de
FourStarSTR	62.3	2.31	132	55.6	69.0	bcd
ThreeStarCUB	59.9	2.31	132	53.2	66.6	b
ThreeStarSTR	61.3	2.31	132	54.6	68.0	bc
PrimeCUB	70.8	2.31	132	64.1	77.6	cde
PrimeTDR	72.0	2.31	132	65.3	78.7	cde
ChoiceCUB	61.4	2.31	132	54.7	68.1	bc
ChoiceSTR	55.8	2.31	132	49.1	62.5	ab
SelectCUB	52.8	2.31	132	46.1	59.5	ab
SelectSTR	47.2	2.31	132	40.4	53.9	a

Estimated Marginal Means- Overall Liking

Table 12. Estimated marginal means of Overall Liking for different EQgrade adjusted for cut

EQ Grade	EMMeans	SE	df	Lower.CL	Upper.CL	Significance
FiveStar	80.0	1.97	138	74.7	85.2	d
FourStar	69.5	1.97	138	64.3	74.8	c
ThreeStar	61.4	1.97	138	56.2	66.7	b
Prime	70.9	1.97	138	65.7	76.2	c
Choice	57.6	1.97	138	52.3	62.8	b
Select	45.1	1.97	138	39.9	50.4	a

Table 13. Estimated marginal means of Overall Liking for different EQgrade by cut

EQ Grade by cut	EMMeans	SE	df	Lower.CL	Upper.CL	Significance
FiveStarCUB	80.2	2.59	132	72.7	87.7	e
FiveStarTDR	79.8	2.59	132	72.2	87.3	e
FourStarCUB	75.5	2.59	132	68.0	83.0	de
FourStarSTR	63.6	2.59	132	56.0	71.1	cd
ThreeStarCUB	61.8	2.59	132	54.2	69.3	bc
ThreeStarSTR	61.1	2.59	132	53.6	68.6	bc
PrimeCUB	66.8	2.59	132	59.3	74.3	cd
PrimeTDR	75.0	2.59	132	67.5	82.5	de
ChoiceCUB	60.2	2.59	132	52.6	67.7	bc
ChoiceSTR	55.0	2.59	132	47.5	62.5	bc
SelectCUB	50.9	2.59	132	43.3	58.4	ab
SelectSTR	39.4	2.59	132	31.9	47.0	a