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Report Title: Value-based pricing system based on carcase yield and eating quality traits

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Abstract

The aim of this study was to calculate the value of diverse carcasses and compare pricing mechanisms on their ability to discriminate variation in meat yield and predicted eating quality. A pervious study in this series concluded that yield was the major driver for carcase price paid per kilogram; even when high premiums for eating quality were applied. However, when communicating the result to industry the response was that this did not reflect their experience. Thus, a dataset that more closely reflected industry reality was obtained in order to understand these divergent views. To do this, data was obtained from the Cooperative Research Centre for Cattle and Beef Quality (CRC, n=9,677), and a subset of carcases having full bone out data, an ossification score, and all other data necessary for determination of MQ4 score and overall MSA Index Score were analysed (n=301). Yield only (YO), and yield and eating quality (YEQ) price and value were determined, and the factors affecting YO and YEQ prices were tested against a series of models, which built in complexity. The results of the analysis demonstrated that with a high eating quality premium, i.e. 50% willingness to pay per MSA grade across all cuts, almost none of the variation in price was accounted for by yield. The pricing calculation used in this instance was therefore likely too great and both overestimated the value of quality, and underestimated the variation in quality. However, it is possible the conclusions are reasonable for commercial processors. More work needs to be done to tailor conclusions for specific supply chains and this work is planned in the year ahead.

Contents

1 Introduction

Beef processor profitability is greatly affected by throughput and so carcass weight is the largest determinant of value. However, increasingly processors are able to extract greater returns from better quality carcasses with quality being determined by meat yield and meat eating quality. Thus, it is important to evaluate the importance of carcass quality traits on price per unit weight to determine appropriate total carcass value. Previous research into beef carcase pricing signals (Pitchford et al., 2020), concluded that yield is the major driver for carcase price paid per kilogram. This was even the case when high premiums for eating quality were applied. However, when communicating the result to industry the response was that this did not reflect their experience. The dataset utilised in that research was small in size and was part of a genetics trial (Pitchford et al., 2002). The boneout trial was conducted across weeks, but as it was a genetics trial, the design was focussed on comparing carcasses that were contemporaries, i.e. born within a narrow time, raised and killed together. Thus, there was likely less variation in quality traits than experienced by processors.

Meat Standards Australia (MSA) has been implemented to improve eating quality consistency, using carcass traits to guarantee eating quality for the consumers (Watson et al., 2008; Bonny et al., 2016). Beef consumers are willing to pay more for high quality beef, particularly when it has been MSA graded (Lyford et al., 2010), with this trend consistent across cultures and countries (Polkinghorne and Thompson, 2010).

Carcase market signals currently are based around grid-based pricing, however they are not well understood by producers and industry improvement is limited (Johnson and Ward, 2005). Grid pricing does not account for any quality aspects of the carcase, and consequently producers are may not be receiving rewards for their high-quality stock, particularly those that satisfy consumer demands (Johnson and Ward, 2005; Polkinghorne and Thompson, 2010). Value-based marketing could be utilised to improve market signals to cattle suppliers, through price and value links to important traits for the consumers, as well as removal of averages from grids (Cross and Savell, 1994; Johnson and Ward, 2005). Price models based continuous pricing strategies could allow accurate carcase description, as well as feedback to the producer, with respect to consumer demand and satisfaction (Johnson and Ward, 2005). If price models include factors related to yield and eating quality, then they may have the ability to improve production efficiency throughout the value chain (Polkinghorne and Thompson, 2010). These producer payments can be linked to eating quality, portion size and yield, then the resultant feedback will enable industry improvement in quality and consistency of product delivered to consumers. That is, by using market signals and rewards, producers may be encouraged to supply high quality carcases which are of consistent eating quality and/or yield. The aim of this study was to calculate the value of diverse carcasses, compare pricing mechanisms on their ability to discriminate variation in meat yield and predicted eating quality, and compare the results obtained here to previous research.

In a separate study (*Summary of yearly, monthly, daily and between and within lot variation in MSA carcase data - ALMTech Technical Report Q3 2021/22*, and Trotta et al. 2022), MSA data was analysed to examine sources of variation experienced by processors. It was demonstrated that the between and within-lot variation that processors experience everyday accounted for a large amount of the variation. In addition, as expected, the variation in quality

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as expressed by marbling, ossification and overall MSA score was significantly greater than in the initial data set. Thus, an additional boneout data set with MSA grading data was sought.

2 Methods

2.1 The dataset

The original dataset from the Cooperative Research Centre for Cattle and Beef Quality (CRC) database was obtained containing 9,677 with a range of information present, with some carcases having all data necessary while others did not. The methods for the breeding program design, measurements and building of the database have previously been described by Upton et al. (2001). The collection methods for the carcase quality and yield measurements has also been previously described by Perry et al. (2001) in relation to the CRC program. For this research to occur it was deemed that the carcases must have full bone out data, an ossification score, and all other data necessary for determination of MQ4 score and overall MSA Index Score. This sorting of carcases brought the number down to 301 individuals which met the data requirements. There was no description of breed or *Bos Indicus* content present within the dataset that corresponded to each animal, thus it was assumed there was very little tropical breed content (TBC), with the individuals likely to be a mixture of temperate breeds and an assumed hump height of 65 was utilised based on previous research (unpublished). The dataset containing the 301 carcases was provided to MSA for generation of MQ4 scores for each of the cuts present.

2.1.1 MSA Index Score

The first round with MSA identified 103 carcasses which did not make grade, due to either meat colour, pH over 5.70, rib fat under 3mm or combination thereof. These animals were adjusted to meet minimum requirements to obtain MSA scores for those individuals, however these adjustments were taken through for the remainder of the analysis. The second round of MQ4 score generation ensured that all individuals made grade. There were multiple scores for each cook method for each primal, so these values were averaged to have a single value for each cook method. To produce an overall MSA Index Score for each carcase a combination of the grill (GRL), roast (RST), slow cook (SC), thin slice (TSL) and corn (CRN) scores were utilised, to represent the most common cook methods. The best scores for each primal were also not used, to better represent the true eating quality of that carcases for common market destinations (Table 1). There were 16 cuts in total, therefore each carcase had a MSA Index score composed of 16 different MQ4 scores based on the most common cook methods.

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Table 1: Primal name, the MSA cook method selected, the mean MQ4 score related to the selected cook method for each primal

Primal	Cook Method	Mean MQ4 score
Blade	Roast	57.40
Chuck	Slow Cook	55.03
Chuck Tender	Thin Slice	56.66
Thin Flank	Slow Cook	61.90
Intercostals	Slow Cook	60.55
Knuckle	Thin Slice	57.06
Striploin	Grill	54.36
Brisket	Slow Cook	49.25
Outside Flat	Thin Slice	58.73
Cube Roll	Grill	65.24
Rump	Grill	56.52
Eye Round	Corn	45.77
Tenderloin	Grill	75.49
Topside	Thin Slice	59.19
Forequarter Shank	Slow Cook	55.09
Hindquarter Shin	Slow Cook	54.43

2.2 Data summary

Summary statistics were completed on the dataset (Table 2), utilising R for all analysis. Hot Standard Carcase Weight (HSCW, kg) was originally recorded as Hot Left- and Right-Side Weights, which were added together to determine the whole carcase weight. Fat depth measures of P8 (P8, mm) and Rib (RIB, mm) fat were measured both hot and cold, however cold measurements are utilised for MSA grading so were used for this analysis. Eye Muscle Area (EMA, cm^2) was also recorded cold. Ossification was recorded at the time of MSA grading, when the carcase was fully chilled to get an ultimate reading, scored out of a possible 590 score units. This was also completed for pH to get an accurate ultimate pH measurement. The marbling score used for this analysis is the MSA Marbling Score scale, scored out of a possible 1190 score units. Saleable Meat Yield (SMY, %) was calculated by dividing the saleable meat weight (SMW, calculated in Equation 1) by the whole carcase weight, and multiplied by 100 to obtain a percentage.

Equation 1: $\text{Saleable meat weight (SMW, kg)} = \text{BLD} + \text{CHK} + \text{CTR} + \text{TFL} + \text{INT} + \text{KNU} + \text{STP} + \text{BRI} + \text{OUT} + \text{CUB} + \text{RMP} + \text{EYE} + \text{TDR} + \text{TOP} + \text{SHK} + \text{SHN} + \text{FAT}$

Table 2: Summary statistics for key variables. Hot Standard Carcase Weight (HSCW), P8 fat depth (P8), Rib fat depth (RIB), Eye Muscle Area (EMA), Ossification Score (OSS), MSA Marble Score (MARB), MSA Index Score (MSA), calculated Saleable Meat Yield (SMY) and pH level (pH).

	HSCW (kg)	P8 (cold, mm)	RIB (cold, mm)	EMA (cm^2)	OSS (score)	MARB (score)	MSA (score)	SMY (%)	pH (units)
Min	138.5	2	0	46	110	100	45.39	54.5	5.41
Max	439.5	28	20	110	350	400	64.12	71.8	6.34
Median	255.5	13.0	5.0	72.0	170.0	270.0	53.80	64.9	5.65
Mean	261.8	13.1	5.7	73.7	169.9	267.6	54.08	64.0	5.70
SD	60.77	5.59	3.47	11.49	19.14	63.31	3.84	3.83	0.166

2.3 Yield Only (YO) carcase value and price calculation

The saleable meat weight was given a basic price of $10 per kilogram to produce an overall YO carcass value. The YO carcase value was then divided by the whole carcase weight (all primals, intermuscular fat, subcutaneous fat, bones and 85% chemical lean) to determine the YO price. Thus, as the mean SMY was 64.0%, by definition the mean YO price was $6.40.

2.4 Yield and Eating Quality (YEQ) value and price calculation

The YEQ value was determined by applying a $5 per 16 MSA unit premium, on top of the basic price of $10 per kilogram for each primal (Equation 2, Brisket primal example), with each of these primal values multiplied by the primal weight and summed to get the individual value (Equation 3).

Equation 2: $Brisket = 10 + ((BRI\ mq4 - 56) \text{ x } \frac{\$5}{16})$

Equation 3:

$$\text{YEQ value} = (Brisket \text{ x BRI weight}) + (Chuck \text{ x CHK weight}) \ldots\ldots.. + (10 \text{ x Trim weight})$$

The total YEQ value was then adjusted to the match the YO total, as the requirement was that a whole lot would not change in value but individuals could be differentiated. The adjusted YEQ value was divided by the carcase weight to determine the YEQ carcase price.

2.5 Testing of YO and YEQ prices

The factors affecting YO and YEQ prices were tested against a series of models, which built in complexity:

1. HSCW only
2. HSCW and P8 fat depth
3. Model 2 plus MSA graded MARB and EMA (The addition of just EMA to model 2 was also tested, however there was little to no change in R^2 value so it was not included)
4. Model 3 plus OSS
5. Model 3 plus SMY (matches previous analysis)
6. Only SMY

The root mean square error (RMSE) and R^2 values were obtained for each model. The Pearson correlation coefficient values were determined to describe the relationship between each carcase variable utilised, YO price and value, and YEQ price and value.

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3 Results

The initial summary statistics (Table 2) results for this study were compared to previous research by Pitchford et al. (2020) to determine if there was better representation of industry variation in the dataset before full analysis was completed. The variation (standard deviation) in marbling score in the Pitchford et al. (2020) study was 39 whereas in the industry MSA data it was 120 and in this data set it as 63. There was no variation in ossification in the original study whereas the daily variation in the MSA dataset was 88 and in this study it was 19. Thus, both quality parameters varied a lot less than in industry, but still varied a lot more than in the previous study.

By definition the YO mean price was \$6.40. The YEQ with total value adjusted to the same value had a lower mean price at \$6.20 (Table 3). The YEQ price also had a lower SD of \$0.272/kg compared to SD of YO price of \$0.383/kg. The YO price also presented the higher maximum price of \$7.18/kg compared to \$6.89 for the YEQ price.

Table 3: Summary statistics for Yield Only (YO) carcase price (\$/kg) and Yield + Eating Quality (YEQ) carcase price (\$/kg)

Parameter	YO	YEQ
Mean	6.40	6.20
Minimum	5.45	5.45
Maximum	7.18	6.89
SD	0.383	0.272

The R^2 values describes the amount of variation in price accounted for by the linear regression model, while the RMSE describes how much variation exists unaccounted for by the model so a simple model describing price would include few variables and have a high R^2 and low RMSE (Table 4).

The values of importance are those for model 3 and 4, and model 5 and 6 for the YO price, as the results are the same for those pairs, with R^2 values of 64 and 100 respectively. These pairs also have matching, or close to matching, RMSE values for YO price, with model 5 and 6 both presenting a value of 0.000, and model 3 and 4 presenting values of 0.230 and 0.228 respectively. The R^2 values of interest for YEQ price were for model 4 and model 6, with model 4 presenting the highest value of 72, and model 6 the lowest of 2. This trend also occurs in the RMSE values, with model 4 with a RMSE of 0.143 while model 6 had a value of 0.246 demonstrating that SMY accounted for negligible variation in price.

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Table 4: Prediction model R^2 values and root mean square error (RMSE) values for Yield Only (YO) carcase price ($/kg) and Yield + Eating Quality (YEQ) carcase price ($/kg)

Parameter	**YO**	**YEQ**
Prediction model R^2		
HSCW (1)	37	14
+ P8 (2)	60	23
+ EMA + MARB (3)	64	59
+ OSS (4)	64	72
+ [3] + SMY (5)	100	60
SMY only (6)	100	2
Prediction model RMSE		
HSCW (1)	0.304	0.231
+ P8 (2)	0.242	0.218
+ EMA + MARB (3)	0.230	0.158
+ OSS (4)	0.228	0.143
+ [3] + SMY (5)	0.000	0.158
SMY only (6)	0.000	0.246

The correlation values for the relationships between the key variables, carcase price and carcase values were tested to determine how much variation could be accounted for by the carcase price or carcase value (Table 5). By definition, the correlation between YO price and SMY must be a value of 1.00, due to the YO price solely calculated on the SMY. In contrast, the value for the relationship between SMY and YEQ price presented a low value of 0.16, highlighting the lack of reliance on yield to drive this price. The correlation values for EMA for both prices are very close in value, with YO price value of 0.47 and 0.46 for YEQ price. The correlation value for the relationship between YO price and MSA index score presented a result of -0.888, which may indicate that a better MSA score may have a negative effect on carcase price. The negative correlation values also carried through to the YO value and YEQ value relationships with MSA (-0.548 and -0.341 respectively), however there was a slightly positive correlation for YEQ price (0.287). Ossification score had small negative correlations with all pricing system types, with YEQ price the highest result (-0.293).

Table 5: Correlations between the Yield Only (YO) and Yield + Eating Quality (YEQ) carcase prices ($/kg AUD) and carcase values ($/carcase AUD) with Hot Standard Carcase Weight (HSCW), P8 fat depth (P8), Eye Muscle Area (EMA), Intramuscular Fat (IMF), MSA Marbling Score (MARB), Saleable Meat Yield (SMY), Ossification Score (OSS) and MSA Index Score (MSA).

Trait	HSCW	P8	EMA	IMF	MARB	SMY	OSS	MSA
Price (AU $/kg)								
YO	0.64	0.75	0.47	0.65	0.52	1	-0.07	-0.89
YEQ	0.39	-0.03	0.46	0.35	0.61	0.16	-0.29	0.29
Value (AU $/carcase)								
YO	0.99	0.67	0.80	0.57	0.50	0.73	-0.14	-0.55
YEQ	0.99	0.54	0.83	0.52	0.51	0.59	-0.18	-0.34

4 Discussion

Beef consumers globally demand leaner cuts, driving beef producers to sell cattle which meet yield grades to receive premium prices (Farrow et al., 2009). Meat eating quality is not fixed, being determined by the consumers in a given market, whom have preferences and opinions for what may be classed as ‘quality’ and ‘valuable’ (Egan et al., 2001). Consumers today are more educated, sophisticated and critical in their preferences, with consistent product quality demanded, and ability to differentiate quality product becoming increasingly important (Egan et al., 2001).

The difference of 20 cents illustrates the possible impact the inclusion of eating quality measures may have on carcase price, due to YEQ price appearing to have been ‘discounted’ (Table 4). This difference may be a function of a number of eating quality aspects, such as marbling, ossification, pH or MSA score. Marbling is one of the carcase attributes utilised in most beef eating quality grading systems (Liu et al., 2020), and is significantly associated with tenderness and flavour of beef, with high marbling having a positive affect on technological and eating quality of beef (Van Ba et al., 2017).

This study again relied on SMY being calculated to form the foundation for the YO price. Ideally, an objective tool would be used for determining this value in future, so that actual carcase composition may be properly reflected, particularly within value-based pricing systems (Farrow et al., 2009).

Pitchford et al. (2020) concluded that even when there is a high premium for quality, beef prices will be driven by variation in yield. However, analysis of industry MSA grading data demonstrated that processors experience far greater variation in quality on a daily basis than that in the initial trial (Technical report and Trotta et al. 2022). Thus, a boneout dataset with MSA grading data and more variation in quality was sourced and analysed. When this was done, it was demonstrated that almost none of the variation in price with a high quality premium (Table 4) was accounted for by yield. Thus, concerns by industry that the previous trial had demonstrated an inflated impact of yield are warranted.

By definition, if processors cannot extract quality premiums, then price is driven by yield only (YO in this report). When this is the case then carcass value is solely a function of yield and so investment in accurate measurement of yield seems warranted. The reality for many beef processors is likely to be between the scenarios modelled herein. Trotta et al. (2022) demonstrated that variation in quality is significantly greater than that herein which means it will be relatively very important in determining appropriate carcass per kg price. However, this depends on a processor’s ability to extract that premium for quality from customers (wholesale and retail). It is likely that the pricing calculation used herein based on a 50% willingness to pay per MSA grade across all cuts is too great. Thus, in reality this paper likely both overestimated the value of quality but underestimated the variation in quality and so it is possible the conclusions are reasonable for commercial processors. Clearly more work needs to be done to tailor conclusions for specific supply chains and this work is planned in the year ahead.

5 References

Bonny, S. P. F., J. F. Hocquette, D. W. Pethick, L. J. Farmer, I. Legrand, J. Wierzbicki, P. Allen, R. J. Polkinghorne, and G. E. Gardner. 2016. The variation in the eating quality of beef from different sexes and breed classes cannot be completely explained by carcass measurements. Animal 10(6):987-995. doi: https://doi.org/10.1017/S175173111500292X

Cross, H., and J. Savell. 1994. What do we need for a value-based beef marketing system? Meat Science 36:19 - 27.

Egan, A., D. Ferguson, and J. Thompson. 2001. Consumer sensory requirements for beef and their implications for the Australian beef industry. Australian Journal of Experimental Agriculture 41(7):855 - 859.

Farrow, R., G. Loneragan, J. Pauli, and T. Lawrence. 2009. An exploratory observational study to develop an improved method for quantifying beef carcass salable meat yield. Meat Science 82:143 - 150.

Johnson, H., and C. Ward. 2005. Market signals transmitted by grid pricing. Journal of Agricultural and Resource Economics 30:561 - 579.

Liu, J., S. Chriki, M.-P. Ellies-Oury, I. Legrand, G. Pogorzelski, J. Wierzbicki, L. Farmer, D. Troy, R. Polkinghorne, and J.-F. Hocquette. 2020. European conformation and fat scores of bovine carcasses are not good indicators of marbling. Meat Science 170:108233. doi: https://doi.org/10.1016/j.meatsci.2020.108233

Lyford, C., J. Thompson, R. Polkinghorne, M. Miller, T. Nishimura, K. Neath, P. Allen, and E. Belasco. 2010. Is willingness to pay (WTP) for beef quality grades affected by consumer demographics and meat consumption preferences. Australasian Agribusiness Review 18:1 - 17.

Perry, D., W. Shorthose, D. Ferguson, and J. Thompson. 2001. Methods used in the CRC program for the determination of carcass yield and beef quality. Australian Journal of Experimental Agriculture 41(7):953 - 957.

Pitchford, WS, Deland, MPB, Siebert, BD, Malau-Aduli, AEO and Bottema, CDK (2002) Genetic variation in fatness and fatty acid composition of crossbred cattle. Journal of Animal Science 80:2825-2832 https://doi.org/10.2527/2002.80112825x

Pitchford, W. S., C. M. Trotta, M. L. Hebart, S. M. Miller, and D. L. Rutley. 2020. Yield measurement is valuable for pricing beef carcasses. Animal production science 61(3):287 - 293. doi: 10.1071/AN20151

Polkinghorne, R., and J. Thompson. 2010. Meat standards and grading: A world view. Meat Science 86:227 - 235.

Trotta, CM, Miller SM and Pitchford, WS (2022) Beef processors experience large variation in yield and quality traits on a daily basis. Animal Production Science 62: clxii doi: 10.1071/ANv62n10–11abs

Upton, W., H. Burrow, A. Dundon, D. Robinson, and E. Farrell. 2001. CRC breeding program design, measurements and database: methods that underpin CRC research results. Australian Journal of Experimental Agriculture 41(7):943 - 952.

Van Ba, H., C. M. Oliveros, K. Park, D. Dashdorj, and I. Hwang. 2017. Effect of marbling and chilled ageing on meat-quality traits, volatile compounds and sensory characteristics of beef longissimus dorsi muscle. Animal production science 57(5):981. doi: 10.1071/AN15676

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