Final report

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Creating and sharing unrealised value through the supply chain (Value Based Marketing)

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Abstract

This project successfully developed an implementation roadmap for a Value Based Trading and Marketing system across five company sites encompassing a large range of cattle types and climatic regions. Operational procedures adopted resulted in significant change in brand marketing, product fabrication, carcase marshalling, payment criteria and producer feedback. Further research provided proof of concept for multiple value adding approaches. While brand pricing evolved to reflect consumer value, delivered by consistently categorised meal experiences, full transition to livestock purchasing has not occurred with further development of yield measurement systems and more stable cattle supply conditions regarded as prerequisites. Supplier communication has however been refined and expanded with the industry aware of the likely transition. The project made significant contributions to industry MSA application including removal of meat colour and addition of retail packaging to eating quality prediction.

Executive Summary

This project examined in detail the opportunities, challenges and operational detail required to introduce a value-based marketing system by a major Australian processor. The transition from traditional trading of livestock and meat to a fully transparent consumer focussed value-based system that both optimised returns from each carcase through delivering superior consumer value, and shared the return equitably across the supply chain, was no easy matter. Further challenges related to establishing principles that could be applied to multiple plants in different geographical regions with very different cattle supply patterns and quality from grass and feedlot production.

P.PIP.5017 continued development and prior analysis in P.PIP.463 which had comprehensively examined the production and related marketing systems utilised in the business from the initial application of MSA grading. In effect MSA grading had been added as a further level over existing processes from cattle purchasing grids to carcase marshalling for boning and to final product packing and description. This had generated revenue through new branded sales under a MSA based consumer focussed offer but had also increased complexity and a degree of confusion between the traditional branding approach of describing cattle or carcase criteria and the alternative MSA empowered approach of delivering consistent guaranteed consumer meal experiences which might be achieved from a broad range of cattle and cuts that were conventionally viewed as different. For context some of the earlier work is re-examined within this report.

The major subject matter was built on the previous base and both expanded and simplified the original premise, made easier by a greatly enlarged proportion of each MSA eligible carcase being MSA graded with cuts eligible for the EQG cipher. This reduced constraint related to carcase marshalling previously driven by additional Eating Quality (EQ) based sortation having to be superimposed over dentition-based categories. By incorporating all major cuts within the EQ based Plant Boning Runs (PBR) all major items could be packed as EQG removing the conflict between harvesting “sweet cuts” as MSA while packing secondary items under dentition ciphers, resulting in either additional boning runs or downgrading to the categories of Prime or Steer (PR or S) on many occasions. The problem of cuts losing MSA eligibility due to freezing under 5 days from kill was also addressed through a small trial. The results indicate that effective ageing proceeds after thawing, raising the potential to improve eating quality through ageing after frozen shipment, noting that the MSA program does not currently recognise post-thaw ageing.

The branding strategy was extensively reviewed and developed on the basis of delivering consistent consumer cooked meal experiences and provenance messaging in conjunction with the marketing and sales teams. This created considerable value in potential returns and, perhaps more importantly, in sales and marketing empowerment. The work was conducted firstly utilising the MSA SP2009 model and further enhanced with the transition to MSA V2.0. A final five tier EQ based PBR structure, differentially applied at regional level to match cattle populations, was introduced successfully to support branding strategies. A major technical handbook was developed to assist sales staff understanding of the technical base supporting the branded program, comparison to other international systems and describing cut characteristics. The ambition was to transition the sales role from being purely transactional to becoming trusted customer advisors, valued for their technical knowledge and ability to adapt product options in a changing price scenario to meet

defined ultimate consumer-based outcomes through alternative solutions. Much of this material was incorporated into ongoing training programs in addition to the numerous workshops, discussions and seminars conducted throughout the project period.

Significant projects were conducted in conjunction with MSA R&D and through collaboration with Texas Tech University (TTU). Project initiated work resulted in the removal of meat colour as an MSA requirement and evaluation of packaging systems; with a consequent penalty introduced for high oxygen MAP retail packaging. Extended ageing in Thermoform was tested and quantified to 140 days for the China market. The packaging work, and earlier study of USA sourced cuts, established that flavour was the principal driver of EQ reduction over extended periods. The flavour chemistry underlying the MQ4 deterioration over extended periods, and in specific packaging, was studied further through an AFBI (Agri-Food and Biosciences Institute of Northern Ireland) sub project that provided detailed information on flavour precursors and volatiles resulting from alternative treatments. Further extensive study to more fully understand these flavour mechanisms and potential commercial interventions to capitalise on the knowledge have been proposed with a major collaborative study involving AFBI, TTU and CSU wine chemistry submitted to MSA.

Major value adding projects, designed to increase EQ and value for lower scoring cuts, resulted in dramatically better EQ from “Texas BBQ” smoking of briskets and ribs, further quantified by muscle, serving style (sliced, pulled or chopped) and served directly after cooking or following a 7-day chilled simulated retail pack period. These studies utilised a complete quality range of Australian cattle and USDA Prime, High Choice and Select cuts tested in Lubbock Texas with paired Australian samples tested at UNE in Armidale. Australian and USA consumers rated product in similar order.

Early work that obtained improved consumer ratings from enhancement with tripolyphosphate, kiwifruit and ficin extracts (P.PIP.0503) was followed by extended work at TTU evaluating the potential for “clean label” enhancement options, utilising lower quality cuts from the carcasses for the brisket and rib and second packaging studies. This work produced very encouraging results utilising a natural beef stock, providing proof of concept for a natural clean label product range. This concept was developed to include the potential impact of differing stock reductions in conjunction with potential natural additions to modify pH and sugar contents pre-cooking. The concept remains to create a natural product with high eating quality by adjusting flavour precursors rather than attempting to cover off-flavour or reduced flavour with marinades after cooking. It is believed that this work has outstanding revenue potential with particular relevance to meat that failed to grade. The existing work suggests that a significant volume of product could be transformed from an MSA ungraded manufacturing quality to MSA 3* and 4* equivalent.

The true relative value of over 2 million individual carcasses was calculated across plants by month over several years. A basic yield formula was utilised pending the availability of more accurate measures with the estimated kg of lean meat within each quality band priced to generate individual animal value. The total livestock payment over each period was redistributed on the basis of true value and compared for each animal. Analyses consistently indicated a greater than $300 per head over- and under-payment within consignments providing considerable potential to improve plant and producer profitability if a VBM payment system was successfully adopted.

The project raised significant industry awareness of VBM principles over several years and engaged in extensive supplier discussion. Overall, these discussions were extremely positive with leading supplier groups keen to be involved and motivated by the potential to improve their efficiency and returns though better alignment with actual plant and ultimate consumer value. As an interim step the estimated lean meat yield of each carcase was added to producer feedback together with graphic representation of the relationship of yield and MSA Index categories. Some producer reservation was also noted, often stemming from low understanding of the detail, but also from a degree of cynicism as to whether the system might be geared in favour of the plant. It was agreed that any transition would require a major effective communication program, preceded by running parallel estimates across company cattle and with selected collaborators prior to full adoption. These concerns were amplified by very tight livestock supply in the final period with any action that could potentially lose supply to other processors of concern.

The calculation parameters were refined over the project period from simple MSA Index and lean meat yield calculations to full application of the brand strategies as they were developed. Very clear and relevant value indicators were recognised prerequisites for VBM. These were identified as separating value that related to HSCW range, market access, non-EQ quality brand provenance criteria and volume related payments from those directly relating to yield and eating quality. Software routines, executed through Shiny Apps in the R statistical package, were developed to provide immediate calculation and production of prototype producer feedback, including graphical presentation suitable for use through an online portal. These routines were also utilised to generate producer return comparisons at the consignment level in addition to individual animal. These analyses indicated that consignments had a range of value which meant that in general current returns would be similar for many producers at the outset with virtually all receiving both substantially higher returns for some animals and substantial discounts for others. Further calculations were built into the software to rank consignment totals relative to their deviation from their actual payment.

This variation provided the primary motive for improvement as the supplier identified factors relating to both the premium and discounted animals. Given that many costs were similar on a per head basis at both property and plant level those delivering more value offered a genuine win:win proposition for both parties. Dairy industry evidence of continual positive milk volume and composition responses to transparent pricing provided a precedent that VBM could drive higher returns for both parties over time and reduced risk from fluctuation if yields and quality.

The challenge of transitioning to a transparent shared value VBM model was judged to be more about industry culture than capability. Widespread adoption required trust and open sharing of information for mutual benefit. The livestock buyer, as for the brand salesperson, should transition to being a trusted advisor rather than a price negotiator. The current yield formula was known to be inadequate, but also known to be many fold superior to existing grid based measures. This indicated that a start could be made, possibly at an initial trial level with willing participants, with upgraded accuracy following improved technology. Arguably the medium and long term industry benefit from a VBM response could be massive and reduce the pricing gap with the integrated pig and poultry industries that already operated in a heavily measured environment.

It was considered inappropriate to launch a new VBM system in a period of unprecedented cattle pricing and tight supply but the data and analysis indicated considerable value under appropriate market conditions.

Table of Contents

1 Background

1.1 Industry background and context

Actual individual animal value has been, and largely remains, poorly described by industry trading systems; for live animal transactions from breeders to backgrounders to finishers and to processors despite livestock being the major enterprise cost in virtually all situations. While breed, sex, age, fat cover and liveweight or carcase weight form the basis for most transactions, potential for subsequent performance is of equal or greater importance. Breeding values provide some valuable data in this regard but rarely extend beyond purchased sire ratings to the dams or progeny at any detailed level.

It is instructive to contrast value-based payment application and subsequent progress between beef and dairy cattle. In the dairy industry individual calf identification is typically related to sire and dam through active daily management of females and extensive AI. Female production is also measured, often at individual cow level through herd testing, in conjunction with milk compositional components that are also individually priced, providing incentives to vary the proportion of fat to protein or total solids. Further milk pricing components include seasonal and microbial incentives or penalties. To complete the circle all herd tested cows and their sire details are processed on a consolidated global platform with breeding values estimated initially by pedigree then updated by actual production.

These linkages between estimated, and progressively actual, production levels coupled directly to farm payment incentives and individual identification drive continuous improvement across the dairy industry at a rate that shows no sign of plateauing.

In contrast the beef value chain is far less detailed with most transactions in effect driven by mob averages and based on dubious visual assessments at all points prior to over the hooks pricing. While processor price grids provide some individual animal value difference, they are generally fairly broad descriptions and fail to accurately quantify and align actual individual carcase value to the livestock price. Further there has historically been a disconnect between the value delivered to a consumer, who effectively pays the bill, and the pricing criteria which traditionally relied heavily on AUS-MEAT language categories applied to the entire carcase and based on dentition and sex. In reality there are two primary value drivers, the weight of edible meat sold and its' eating quality, with a third co-product category also contributing.

The introduction of MSA and its continuing evolution has delivered accurate prediction of the consumer value derived from individual beef meal outcomes. This has been a dramatic improvement over single whole-of-carcase descriptors and enabled meal level description, and related pricing, based on expected sensory experiences.

The yield component of value, while of no consumer interest, remains a critical and traditional focus for processors. To fully deliver a value-based system both components need to be integrated. This project was strongly focussed on the consumer facing eating quality, in essence the $/Kg component, with other major company and industry research targeting accurate yield estimation, in essence the weight of each quality band to be sold.

Existing MSA predictions relate to raw beef being purchased and cooked on typical household appliances. Some cooking methods, more typically aligned with restaurant or industrial cooking, have been evaluated under MSA protocol with the objective of inclusion in the prediction model but, prior to this project, very limited work had been done on value adding processes that involved treatment of raw meat in conjunction with cooking. These industrial value adding treatments offer important potential to add value, to raise cuts that might fail MSA benchmarks to a consumer accepted standard and to be potentially applied to ready to eat (RTE) or ready to heat (RTH) meal production.

Further areas of interest, and of particular relevance to export marketing, related to extended ageing beyond the 35 day model estimates and potential interactions with packaging systems.

Beef branding strategies have typically included one or more provenance criteria such as breed, feeding system or supply region. Prior to MSA adoption any eating quality message applied to a brand was limited in accuracy and principally related to cut and assumptions of simple correlation with limited observed criteria including marbling and breed.

The advent of MSA provided a powerful tool to increase accuracy and to align with a meal rather than cut description base. Translation of the underpinning science to practical commercial application at scale however required considerable detailed understanding of existing systems and prospective challenges relating to physical facilities, existing brand criteria and culture at both business and customer level.

This project examined in detail the opportunities, challenges and operational detail required to introduce a value-based marketing system by a major Australian processor. The transition from traditional trading of livestock and meat to a fully transparent consumer focussed value-based system that both optimises returns from each carcase through delivering superior consumer value, and shares the return equitably across the supply chain, is no easy matter. Further challenges relate to establishing principles that can be applied to multiple plants in different geographical regions with very different cattle supply patterns and quality from grass and feedlot production. Lastly, but by no means least, was the need to communicate and gain acceptance of a new approach to buying livestock and supplying final product.

The opportunity, and significant consequence, of adoption however is to deliver continual industry improvement through greatly enhanced efficiency, profit and relevance at each level through instilling a consumer value focus in every production step and transaction. The primary challenge remains culture and acceptance of the benefit of truly transparent pricing mechanisms.

1.2 Background from the project contract

An extensive description of the background of the project was included within the project application and contract documentation. This is reproduced below, with expansion to the identified focus areas reproduced in following subheadings which are also utilised in describing methodology and results for consistency.

The plan is to deliver transformational change throughout the supply chain and to the greater industry via development and implementation of a comprehensive Value Based Marketing (VBM) system.

However, the development of the proposed system has slowed due to other external factors increasing in significance that have to be incorporated into the design of the VBM process. Those are the outputs of a number of projects developing Objective Carcase measurement technologies (ALMTech). These ultimately will enhance the VBM project.

1.3 Focus Area 1 - Value Based Marketing (VBM)

The core principle of the project is to accurately identify value impacts at each point of the supply chain and to directly align communication and price signals. It is recognised that all value flows from the final consumer purchase, but also that it is dispersed and often distorted by intermediate sectors. These range from distribution and marketing channels to livestock supply systems.

A fundamental component of the initial focus point will be to determine the most appropriate measurement of yield to support the VBM system. Over the course of the initial project significant related work has progressed under the ALMTech initiative. Outcomes from this will provide substantial knowledge and prospective technology outcomes. Further work, in conjunction with MSA where appropriate, has addressed issues with meat colour and retail packaging influence on eating quality. Further potential MSA grading inputs including measures of animal stress at slaughter and effects related to long distance transport by road or rail and recovery strategies together with packaging innovations will be pursued within this project. As true carcase value is the sum of the direct extension of weight by satisfaction level for each carcase component both yield and eating quality estimates are crucial to project success.

Up to this point producers in general have been very receptive to VBM and related projects such as Analysis and Extension to support Beef producers in improving animal health performance (P.PIP.0753), Supply Chain Feedback (P.PIP.0565), and Supply Chain Capability Building for producers (P.PIP.0473). The next step in this process will be to finalise the detail of the model and then “sell” that detail to a core group of producers to champion to system. Part of that sell must be to get the same producers to understand and utilise the various data outputs of the slaughter and grading process.

1.4 Focus Area 2 – Re-branding according to Eating Quality

The additional consumer value will be delivered via a new branding strategy utilising MSA grading data at an MQ4 level (MQ4 is the Meat Quality score from four attributes, which is a numeric measure of the consumer’s acceptability of a piece of beef incorporating tenderness, juiciness, flavour & overall liking) to accurately stream product into consistent quality levels, further supported by alternative grass and grain fed provenance positions. This represents transformational change in moving from traditional carcass category-based product description to a focus on consumer assessed satisfaction. Further development challenges include assessment of consumer satisfaction and related benchmarks within market and distribution segments, critically including key international markets.

The project includes significant development work including modelling of current cattle supply across seasons and plants to determine supply challenges or constraints and to predict product volume within proposed brands including grass and grain fed streams.

Required modelling must quantify not only the distribution of each cut/muscle within MQ4 score related bands but also the efficiency with which they can be harvested by optimised carcase sorting at individual plants. Differences between the two outcomes will influence the strategic importance of future boning room systems and cut identification. Initial challenges may impact capital expenditure requests for enhanced carcase marshalling whereas longer term implications could significantly impact boning room design and allied cut traceability technologies. Significant implementation issues include managing the transition from AUS-MEAT category based to brand-based (eating quality) carcase marshalling with associated implications for code and label management and transition or acceptable complementary arrangements for specific international markets or major domestic customer specifications.

A further critical strategic component is empowering the marketing transition of conventional, predominantly AUS-MEAT category based, description to the new branding strategy. Company marketing and sales staff must firstly understand and comprehensively adopt the new branding philosophy and be educated to ensure its benefits are aggressively promoted to customers. The project includes an educational component to enhance understanding of the consumer-based standards being implemented and the supporting science and technology. Involvement of both sales and marketing staff, and key customer representatives in the allied consumer evaluation studies, is considered an important supporting activity.

1.5 Focus Area 3 - Value adding to enhance eating quality and customer value

Significant project activity is included to monitor consumer satisfaction in both key markets and across existing and new products. Important components are company-initiated consumer testing, support for enabling work in flavour evaluation and adoption of a formal consumer evaluation process for product development and marketing strategies.

The project utilises existing MSA sensory testing protocols and linkage to Australian and, where available, international consumer data. Further protocol extension is planned to evaluate additional cooking alternatives with particular emphasis on those currently not within MSA but of strategic importance in target markets, China being an example. It is planned to directly test branded product and potential new product offers in identified markets and distribution channels, with active engagement of customer representatives encouraged to build awareness and commitment together with optimum product targeting.

While current MSA prediction is restricted to fresh product cooked by domestic appliances the project will extend this to prediction of consumer outcomes when product, with that of low initial value a priority, is further value added by potential commercial processes. Simple immediate examples include corning and marination with longer term objectives including RTE (Ready to Eat) pre-cooked offers. Critical research questions to be addressed include the interaction between initial raw material standards, including MQ4 level, and the further processing technology and control. It is intended to document the process outcome predictions as open source code related to initial MSA model outcomes. Over time it is expected that collaboration with other groups and international researchers will establish universal consumer-based description to support validated value added processes. Detailed Standard Operating Procedures (SOP) must be developed and their interaction with raw MQ4 investigated and documented.

Monitoring of associated flavour responses is regarded as fundamental to this product development activity and a collaborative arrangement under the direction of Dr Linda Farmer from AFBI (Northern Ireland), a highly experienced flavour chemist, is included. From early MSA related studies it is considered that more complex flavour prediction may be possible and able to be implemented within the branding framework.

An intrinsic outcome from extensive consumer based product evaluation is the capacity to merge muscles of common eating quality under a single outcome based description, possibly via trademarked products within the branding strategy. This has potential to simplify retail and trade channel description while improving product consistency in comparison to traditional cut based terminology. Allied benefits may be a reduction in codes packed and further processing versatility through the ability to meet defined cooked product outcomes from alternative muscle combinations. Such approaches will be explored within the project plan with wet cooking styles prioritised and a longer term progression to grilled cuts.

2 Project Objectives

2.1 Project Objectives

The project objectives were defined as: The participant will achieve the following objective(s) to MLA's reasonable satisfaction:

1. Finalise a working model for a value based marketing program
2. Pilot a key Value Based Marketing program with key producer groups
3. Review current eating quality based programs and conduct further research to enhance the developed innovative branding program
4. Conduct further research and development to develop an innovative value adding program that improves eating quality and consumer preference
5. Develop the people and systems capability within the processor and selected producers and customers to implement and support a value based marketing program

2.1.1 Prior work

P.PIP.5017 continued development of a considerable body of prior analysis and development activity encompassed in P.PIP.463. This earlier activity comprehensively examined the production and related marketing systems utilised in the business from the initial application of MSA grading. In effect MSA grading had been added as a further level in addition to existing processes from cattle purchasing grids to carcase marshalling for boning and to final product packing and description. This approach had generated revenue and expanded a portion of sales to an MSA based consumer focussed offer, supported by base brands. It had also increased complexity and a degree of confusion between the traditional branding approach of describing cattle or carcase criteria such as breed, marbling and meat colour and the alternative MSA empowered approach of delivering consistent guaranteed consumer meal experiences which might be achieved from a broad range of cattle and cuts that were conventionally viewed as different.

2.1.2 Related projects

As detailed work proceeded a number of related projects were developed and delivered to examine the potential to enhance consumer value by alternative value adding processes, to examine the sensory impact of packaging and to extend cattle supply options. These projects interacted with the core project, expanding its' scope and quantifying technical potential of various processes. Related projects included:

- P.PIP.0503 - Investigation of the interaction of selected value-added processes on selected cuts of varied quality.
- P.PIP.0488 - Impacts on consumer acceptance of beef from interactions between pH, meat colour and packaging.
- P.PIP.0550 – Developing capability for external strategic partnerships with experts from Texas Tech University (TTU) Meat Sciences and Muscle Biology Program.

These projects stimulated and interacted with other MLA levy funded projects including:

- L.EQT.1813 - Quantifying the impact of Modified Atmosphere Packaging (MAP) and alternative packaging solutions on eating quality.
- L.EQT.1814 - Sensory evaluation of Australian and American briskets, striploins and ribs by Australian and American consumers utilising genomic tested cattle.

The project work interacted extensively with other MSA research activity including the company being a partner in a large scale dairy beef project including use of company feedlot and slaughter facilities and providing kill and cut collection for two extensive road and rail transport projects.

- P.PSH.1023 - Creating a dairy beef supply chain to increase the value and volume of beef and veal products.

Each of these projects, through knowledge and data derived from them, have contributed to further development and commercial application of MSA science and stimulated further research activity related to animal stress pre slaughter, livestock management during extended transport by road or rail, potential genomic relationships to eating quality, extended ageing and ageing post freezing and thawing to facilitate export marketing.

Direct industry impact has included the removal of meat colour as an MSA grading requirement (P.PIP.0488) and the addition of a high oxygen MAP retail packaging penalty (L.EQT.1813).

The project, with its' strong focus on value derived from consumer assessed eating quality, has been conducted in parallel with other extensive company, MLA and ALMTech work related to accurate yield estimation, the other principal component of value based livestock trading.

3 Methodology

The methodology was developed to provide high quality objective data, leaning heavily on existing meat science knowledge where possible and building upon it where needed. This included extensive collaboration with both local and international scientists. In particular, extensive collaboration through a matched funding process with Texas Tech University was established, as were contracted arrangements with the Northern Ireland Agro-Forestry and Biosciences Institute (AFBI) who provided specialised flavour analysis. Further relationships of significant value were established with Professor Melvin Hunt of Kansas State University and with the Irish Cattle Breeders Federation (ICBF).

The critical need to directly and deeply engage with operational personnel at all levels was also recognised from the start as their detailed knowledge of their work areas and operational practices was invaluable and their direct engagement in introducing change essential. All the suggested operational changes were workshopped on the “factory floor” as a component of developing recommendations in addition to higher level discussion with senior management. At operational level, application of common principles required plant specific adaption relating to the cattle population and to physical facility differences.

Software integration also evolved as the company consolidated individual site based systems to a common platform.

3.1 Focus Area 1 - Value Based Marketing (VBM)

3.1.1. Existing system analysis

The initial project step was familiarisation with both the physical plant facilities across all participating sites, their cattle populations and personnel. An initial meeting with the marketing team was held to establish existing brand specifications and clarify future aspirations. This involved detailed discussion and explanation of differences between standardised MSA boning group constraints and the potential to specify individual MQ4 based score ranges.

The cattle procurement team was consulted many times to clarify allocation of purchased groups to kill order and how documentation was managed and transferred to the IT system. Key issues were identification of MSA eligibility, HGP status, market eligibility and documented bos-indicus %.

Many meetings were held with senior production staff responsible for carcase marshalling and allocation to boning and subsequent product code labelling, to firstly understand the current decision-making process, and then how decisions were communicated and applied from livestock supply to carton despatch.

Further discussion was held with the IT team to determine how any subsequent change to operational practice could be delivered and whether this would be arranged as a stand-alone Birkenwood installation delivering sort designations or integrated within the IT system.

Monthly data was extracted from company systems for each plant including livestock, slaughter floor and MSA grading fields together with MSA eligibility and Boning Group assignments.

These combinations of historic data and production practice formed the basis for analysis scenarios and development of draft proposals. Birkenwood software was utilised to calculate MQ4 scores for all nominated cuts and, from these, carcasses were allocated to proposed boning room runs. These runs were then tested against individual plant constraints including chiller space, ability to segregate during marshalling as limited by the number of feeder rails, space and number of boning room changeovers. Extensive on-plant observation and discussion was conducted to workshop proposals and test the practicality of various options with those controlling daily grading, marshalling and boning.

The cooperation and assistance from personnel at all levels was outstanding and very much appreciated.

3.1.2. Application related to the MSA SP2014 prediction model

During the initial project phase the kill schedule was largely assigned on market eligibility, primarily EU with a small number of organic, feed type and HGP status. Allocation to the chillers off the kill floor was determined by dentition category, carcase weight range then MSA eligibility. The MSA SP2014 model was utilised in MSA grade calculations with the primary management of MSA eligible carcase sorting established by the fixed MSA Boning Groups. MSA graders evaluated the carcases and applied stickers to indicate a sort group for carcase marshalling for boning.

This process made MSA an additional requirement adding considerable complexity to daily chiller and boning room management. Further, a limited number of high value primal cuts were packed as MSA with most secondary cuts packed as non-MSA, and therefore merged after boning with those from non-MSA.

Early analysis evaluated the MSA Boning Group allocations relative to dentition category which was expanded to further detail of individual cut MQ4. This was complemented by discussion and explanation via some PowerPoint presentations to convey the interaction, and inherent conflicts, of Boning Groups and individual cut based MQ4.

Further analysis and comparison was conducted of accurate group bos-indicus definition relative to entering “110” and accepting the MSA adjustment calculated from hump and carcase weight. Again, this was presented and discussed in plant meetings supported by written material and PowerPoint display.

Detailed individual cut x cook MQ4 calculations were then conducted utilising Birkenwood software installed in a cloud-based system accessed via a portal. These analyses for each month and plant created individual cut MQ4 distributions for chosen subgroups including grass and grain fed, HGP and HGP free, dentition classes and MSA Boning Group. Further modelling was conducted to evaluate the likely impact of tenderstretch carcase suspension.

From extensive analysis, draft individual cut settings with specified MQ4 cut offs for related cooking methods and days ageing were created as a proposed approach to carcase sorting based on simplifying processes while delivering eating quality defined brands. Initial application upgraded existing settings in small steps with continual monitoring and some single site trials. As the program developed it was introduced across all sites with Birkenwood software embedded in the IT system and utilised to develop settings for input into the plant management software.

3.1.3. Upgraded application for the V2.0 MSA prediction model

The introduction of a new MSA model some years after introducing the first Birkenwood developed system provided the opportunity and challenge to greatly expand application of EQ based grading and associated brand marketing. The new MSA model provided close to double the potential cut x cook alternatives, extended ageing periods to a more export focussed 50 days, introduced additional cook types, removed meat colour as a screening variable and imposed a penalty on MAP packaging. This was truly a new model from the ground up with hump height replacing the original bos-indicus % entry and major changes to the calculation process.

To enable the complexity of calculation required a major upgrade of the Birkenwood software which was undertaken six months prior to the new model implementation. In addition to providing the alternative models for comparison, further non MSA categorisation relating to branded product provenance was included in addition to adding the new cut x cook alternatives and further capacity improvement.

Extensive comparison was made between the new and old models across cattle types, plants, HGP treatment, etc. following which draft settings were produced. This process was followed by extensive engagement with the marketing and sales teams to workshop brand settings and related offtake using 12 months of historic data for each plant as a base and for comparison.

As for the earlier settings, the proposed sorting criteria for carcase marshalling into boning room runs was extensively workshopped with operational staff at individual plants to identify potential practical, and to some extent personnel, issues. This was expanded after on-plant discussion from the base month by plant base to modelling of daily boning run numbers and changeovers comparing existing practice with that proposed. On site input added great value and expanded potential strategies to manage out additional complexity including suggestions relating to processing of specific cattle types on limited days to increase boning run numbers and further management of kill order to concentrate cattle types into a lesser number of chillers, thereby reducing post grading sort complexity and resulting multiple runs of a single category.

After agreement on final Brand criteria a detailed marketing manual was produced to assist sales staff in optimising customer results with more flexible cut x cook options that could deliver similar eating quality outcomes.

3.1.4. Value Based assessment and calculation

Effective consideration of a VBM system required considerable background data and working knowledge of existing company trading systems and policy. These data were developed from several years of company data, analysed on a monthly basis within plant and subsets of grass and grain fed cattle. Further subsets of cattle types and of cattle meeting brand specifications were added.

Also integral to the process was the background transition from MSA boning groups applied over traditional AUS-MEAT cipher to primary assessment via the MSA SP2014 model and the upgraded assessments produced utilising the MSA V2.0 version. This transition, while subtle, reflected a significant change in fundamental processes as final product sorting and packing moved from primarily reflecting visual animal and carcase traits including dentition, weight and sex to MSA predicted eating quality.

Value to the business became more aligned to consumer satisfaction, with stronger brands priced at higher levels on the basis of ultimate consumer satisfaction and related value.

3.1.4.1 Yield assessment

Yield is an integral component of any VBM calculation setting the weight to be priced. Yield must also be defined with saleable (SMY) and lean (LMY) meat weight recommended by different groups. SMY had initial attraction as it could be directly measured and, at first glance, measured the product actually sold. However, this assumed a single standard cutting line and trim across all cuts. In the business this was totally unrealistic given the plethora of markets supplied and constantly varying specification of individual cuts as reflected in product codes, major loin cuts having around 100 individual codes, many of which reflected cutting specifications.

It was agreed that the preferred standard weight basis for VBM communication should be LMY as this reflected total lean muscle mass, a constant measure that applied across time and market allowing consistent communication. The quid pro quo however was that all product codes needed sufficient detailed yield testing to establish reliable conversion from an LMY base.

This was a recommended action central to enabling market pricing to be related to lean meat content.

Yield can be either directly measured or predicted with varying accuracy. Existing OTH pricing grids typically pay on hot standard carcase weight with adjustments for sex and P8 fat as yield proxies; the use of butt shape in pricing having been discontinued in recognition of its inaccuracy. In practice, fat adjustments are applied above or below set thresholds and grouped in bands such as 23-32 or 43-49 introducing further variation in addition to the inherent difficulty of extrapolating a single point measure to an entire carcase. The proxies used, while traditional and understood, deliver very low accuracy so that almost any new system is likely to perform better.

Early discussion with Professor John Thompson, a pioneer in yield assessment science and CT technology, reappraised a large data set from earlier yield trial work. Professor Thompson produced yield estimates comparing the existing system and the option of measuring a number of carcase portions pre-trimming to extend to whole carcase estimates. This approach was based on reports by Butterfield that muscle weights were highly correlated as change in relative mass would only occur with extensive change in use, unlikely for cattle. The results presented indicated that yield estimates could be greatly improved by measuring carcase portions. Practical issues were which portions were suitable through having sufficient mass and being largely unaffected by alternate cutting lines. A working proposal to consider weighing the butt by installing a load cell within a side chain was considered but deemed to be impractical.

As an interim step yield formulae for males and females developed by Murdoch University from a moderate sized dataset were adopted for project evaluation purposes. The LMY% calculation utilised left side carcase weight, sex, eye muscle area and rib-fat depth inputs, each sourced from production data.

While generalised VBM calculation was conducted on the basis of total carcase lean meat kg further boning yield estimates were utilised to calculate individual cut, trim, fat and bone weights. These estimates were based on existing yield tests and, for some proposed muscle based derivatives, on Polkinghornes Pty Ltd yield data recorded from over 5,000 carcasses where all portions had been individually weighed and recorded.

3.1.4.2 Combining yield and eating quality for a VBM output

Initial VBM modelling utilised the Murdoch formulae to produce a lean meat % estimate for each body which was multiplied by HSCW to create a lean meat kg estimate. The consumer value component of a basic LMY * $/LM kg calculation was initially related to indicative Good, Better, Best MQ4 based bands with sensitivity analysis applied by varying the price differentials between non MSA product and the proposed Good, Better, and Best categories.

For analysis purposes it was elected to compare alternative systems within a common total livestock expenditure, set as the actual gross livestock cost for each plant in a given month. This assumed that total livestock purchase cost would be constant with the VBM effect related to redistribution according to the individual body true values. This enabled examination of the degree of "true value" variation across the cattle supply and individual animal discount or premium adjustment against a common total pool value.

A number of alternative individual body pricing approaches were compared:

- Payment entirely on kg of lean meat (LMY).
  Calculated as (total Pool$/total LM kg)*individual body LM kg
- Payment entirely on MSA Index as a proxy for eating quality.
  Calculated as ((Body HSCW x Index)/(Total Hd HSCW*Index)) * Pool$
- A combination of 1 and 2 set at 50% each but able to be varied.
  Calculated as (LMY $ + MSA Index $)/2 (or varied proportion to each)
- Payment on brand (Best, Better, Good, Ungraded). Calculated as (Body HSCW * Brand $/kg HSCW) *(Pool$/total Hd HSCW*Brand $)
- VBM payment utilising pre-set but variable $/kg Lean Meat values by Brand. Calculated as ((LMkg * Brand $/kgLM)/(Total Hd LMkg * Brand $/kgLM))*Pool$

The first approach represented a pure yield basis, the second pure eating quality based on the MSA Index and the third a weighted combination. The last two approaches multiplied the LM kg by either a HSCW or LM Kg price for each brand category. The difference from the actual price paid for each body was then computed for each of the 5 alternatives and summary statistics run for the group.

As the branding program was activated, pricing was related to MSA plant boning runs (PBR) as these underpinned the various brands utilising the Murdoch formula for yield. The first three options were dropped and concentration placed on the brand and VBM alternatives. Detailed discussion was held regarding other plant unit costs that materially impacted value such as carcase weight and to clarify value differences that related to market access, brand provenance or supply volume or timing.

This information and the analysis data was then utilised in developing prospective pricing grids and draft feedback content including a Shiny App utilising R code to provide an online producer visualisation tool that also enabled sorting and display options.

The calculation process was re-run against actual pool values for 10 months production by plant after introducing the V2.0 MSA model and the associated brand setting adjustments. Further analysis was conducted on a purchase group basis to evaluate the degree to which individual suppliers might be impacted within a net zero pool.

Final analysis produced more complex value assignment by deducting non yield and eating quality additions and deductions prior to calculating the yield by brand assignment on the remaining pool$. Findings were shared widely through company meetings and one on one presentations at each analysis stage.

Individual cut/muscle weight estimates were applied to detailed production modelling. For this work the average HSCW for each brand based PBR, for each plant, month and grass and grain, was extended by the adopted cut yield% to generate weight estimates for each cut. These weights were summed to provide a total number and weight for each cut within each branded quality group, this in turn being multiplied out by nominated brand based pricing and by non-branded values to enable comparison.

3.1.5 Company training and capacity development

Presentations and workshops were a continuing feature of the project from inception and included conducting a meat science course for senior management with Professor Thompson, together with presentations at plant and head office level with livestock, production and sales staff. These presentations successfully sought engagement and input from participants in conjunction with presenting knowledge and workshopping potential application approaches. Specific training courses were developed for sales and marketing and strongly supported by management who believed knowledge of MSA science and application was a required core competency.

3.1.6 Statistical evaluation

Statistical analysis was entrusted to Dr Garth Tarr of Sydney University and Professor Ray Watson, the developer of all MSA models to date. Dr Tarr developed a number of Shiny App routines linked to the R statistical package to visualise data analysis and in particular to provide potential on-line producer feedback suitable for use within a VBM payment system.

3.1.7 Software development

The initial Birkenwood software was extensively upgraded throughout the project and adapted to be more business specific. A significant IT benefit was establishment of a remote access arrangement that allowed analysis to be conducted from off-site locations.

3.2 Focus Area 2 – Re-branding according to Eating Quality

A primary project deliverable was to assist the marketing team in transitioning all company brands to an eating quality basis. This included adapting standards to existing brands, reviewing current and prospective non eating quality provenance criteria and developing new brands. The reference point was an initial and progressively developed a business brand map depicting desired combinations of provenance and eating quality criteria.

3.2.1. Base scenario

At project inception the brand strategy reflected traditional approaches prior to MSA introduction with the primary sales reference point for domestic and export customers being AUS-MEAT cipher related with orders based on YP, PR etc. and further division into grain or grassfed production denoting combinations of dentition and feeding system as surrogates for quality. In common with other industry members further provenance related divisions had been superimposed on this base with Angus the major provenance descriptor.

The marketing team had identified considerable eating quality variation within these categories and had initiated an MSA based overlay by using MSA Boning Group categories to improve product consistency and related value. A comprehensive understanding of alternative potential eating quality based approaches, their effectiveness and practical implementation challenges were central to the project objectives.

The desired end result was a "brand map" that could simply deliver clear well differentiated brands that provided distinct well segregated combinations of eating quality and provenance.

3.2.2. MSA Boning Groups and limitations

The MSA boning group system was introduced by MSA to provide a standardised national system to differentiate eating quality, defined as 3*, 4* or 5* for cuts when cooked by specified methods after specified days of ageing. This was initially a valuable platform for industry to transition to an eating quality base with reduced complexity.

The basis for MSA Boning Group levels was the predicted MQ4 score for defined cut x cook by days aged combinations and associated MSA grade. The individual MQ4 score for any cut was a weighted sum of four sensory scales each with a range from 0 to 100. The tenderness scale was multiplied by 0.3, the juiciness by 0.1, flavour liking by 0.3 and overall satisfaction by 0.3 to create the single MQ4 score. The MQ4 score was created by the MSA prediction model software with grades defined by upper and lower MQ4 values. Both the prediction and the grade boundaries were the result of expert statistical analysis with the MSA Pathways Committee acting as the peer review mechanism.

MSA grades were defined as Unsatisfactory (less than 46 MQ4), 3* (from 46 to 63 MQ4), 4* (from 64 to 76 MQ4) and 5*(over 76MQ4) with values rounded. While calculated at MQ4 0 to 100 level the MSA output was restricted to Ungrade, 3*, 4* or 5*.

One side of the MSA Boning Group table for AT hung bodies is displayed in Fig. 1. There are 18 different boning groups shown, each on a row depicting MSA grade outcomes for different cooking methods within each cut. The colours depict grade; gold for 5*, purple for 4* and green for 3*. The numbers within any cell denote a minimum days ageing required with a blank indicating 5 days. Further cuts were displayed on the reverse side of the chart.

To achieve a given Boning Group every value on the row had to be met or exceeded meaning that any that failed would result in the carcase dropping to the next row and being checked against that groups settings until it either achieved all settings or dropped out as ungraded. The number of cuts decreased with lower boning group and minimum ageing days increased to meet the required minimum grade scores. The final Boning Group also determined the carton label description, for example MSA GRL 3* @5 days, 4*@14 days, MSA RST 4*@ 5days.

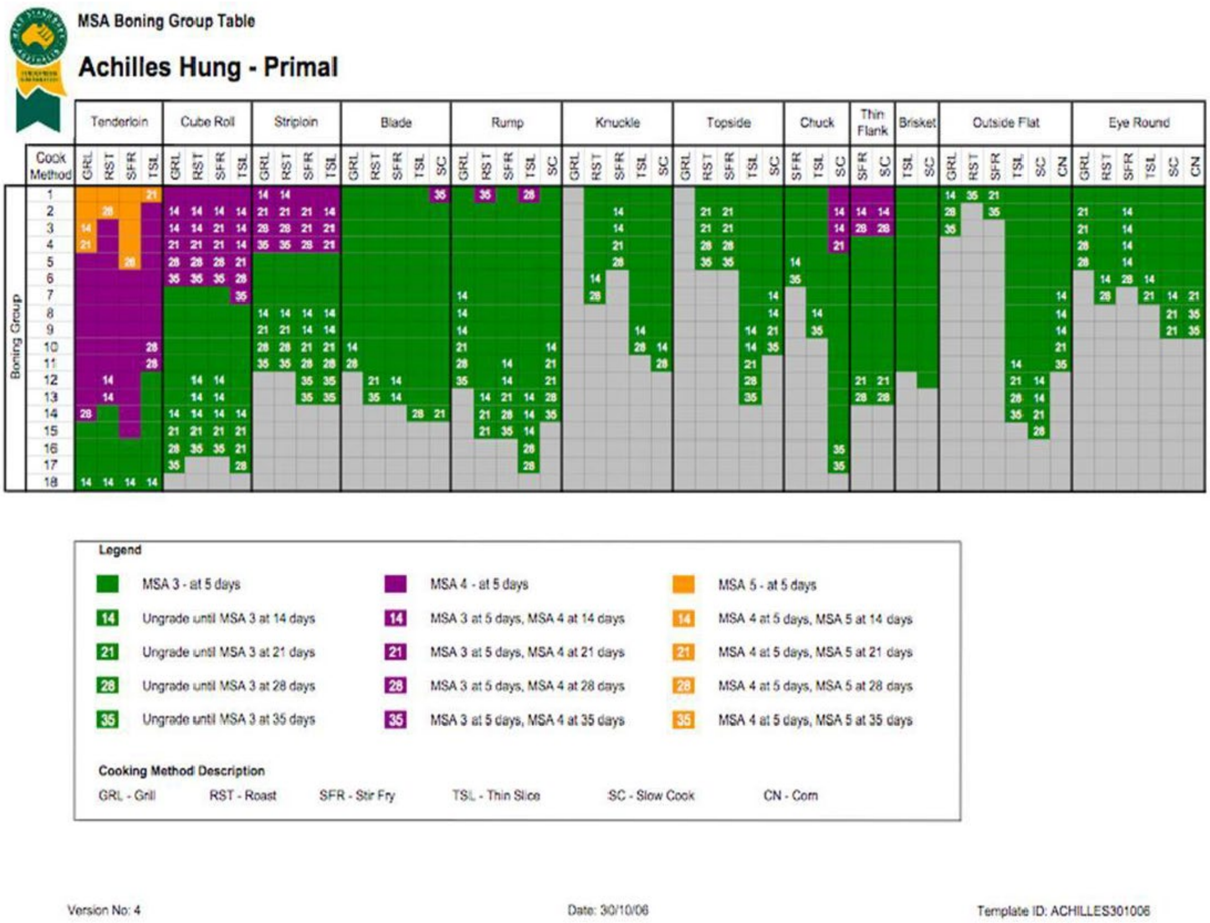


Figure 1. MSA Boning Group table for AT hung carcasses (Version No 4, 30/10/2006)

To reduce the number of boning room runs most processors elected to group Boning Groups into bands with plants grouping Boning Groups. This reduced number of boning runs limited plant complexity and enabled MSA criteria to be applied as an addition to the existing sorting on dentition and weight categories within market eligibility.

While simple to understand this simplicity also resulted in inefficiencies both through increasing the variability within each cut as boning groups were merged and in cuts harvested within each category due to "the first cut to fail" in effect downgrading all others on that body as well. This problem was exacerbated by the fact that, while all cuts in the Boning Group table had to meet all their individual values, many were often not packed as MSA causing desired cuts that met MSA standards to be lost due to other cuts that were not packed for MSA based sale failing.

Additional issues related to variation in the relationship between cut MQ4 values for various cattle classes and across hanging methods. Separate MSA Boning Group tables were generated for AT and TX hanging methods but both tropical breed content and HGP treatment created significant differences and increased failure rates as illustrated in Table 1.

Even within a single boning group some cuts could be well above the label specification as the group was determined in effect by the worst cut by cook MQ4 score. The difference between the actual MQ4 score and the label specified minimum varied widely between cattle in line with the relationship of individual cuts for different cattle types. For example, large differences in the relative MQ4 of principal cuts resulted from HGP use and bos-indicus %, as demonstrated in Table 1.

Table 1. Example of MSA Boning Group impact across cattle breed type and HGP implant status

			At average Feb 2012 values				At first cut failure borderline			
			TDR	CUR	STR	RMP	TDR	CUR	STR	RMP
		BG11 Settings	64	47	47	47	64	47	47	47
		COOK	GRL	GRL	GRL	GRL	GRL	GRL	GRL	GRL
		Daged	5	5	35	28	5	5	35	28
TBC%	HGP	HUMP								
0	N	50	78	64	64	55	69	55	55	46
0	Y	50	73	55	59	52	67	49	53	46
50	N	90	75	60	57	54	67	52	49	46
50	Y	90	70	51	53	50	66	47	49	46
100	N	120	72	56	50	52	68	52	46	48
100	Y	120	66	48	46	48	66	48	46	48

Model output based on Feb 2012 Beenleigh population.
HSCW=316, UMB=320, UOSS=170, Male

Most likely cause of Ungrade (pink)

Next likely cause of Ungrade (yellow)

Important point is **relative** cut scores.

The lefthand table shows the relative MQ4 scores for an example carcass after adjustment to HGP and TBC% in relation to the Boning Group 11 minimum values at the top. It will be noted that the 100% TBC HGP carcass has all cuts close to the minimum settings. In contrast the 0% BI HGP Free carcass has a tenderloin score 14 above the minimum with the cube and striploin 17 above and the rump 8 points. The righthand table adjusts the scores to demonstrate what the scores would be when the first cut failed. Unlike the 100% TBC HGP carcass it can be seen that when the rump fails in the 0% HGP Free carcass the other cuts are still 5 to 12 MQ4 points above the minimum.

From these examples it can be seen that MSA Boning Group could result in considerable variation and often considerable loss of cuts harvested.

3.2.3. Transition to an MQ4 allocation basis

To overcome the inherent limitations of the MSA Boning Group system Birkenwood had developed sophisticated software that operated at MQ4 rather than MSA grade level, although these were able to be readily determined from the MQ4. The underlying principles of the software had evolved and been refined through 10 years of development in the Polkinghornes retail store system where all cuts had been sold based on a cooked outcome, for example 4* roast or 3* stir fry, rather than cut name. This had required individual cut MQ4 to be calculated at boning and adjusted for ageing on a daily basis until transferred to the retail stores. Cuts were individually weighed at boning and identified to enable the tracking of MQ4, retail yields and value from live animal to final retail sale.

The software, and related experience and data, was then adapted to provide a massively scaled up solution that could be applied within the high volume plants, each of which had different cattle supply populations and physical layouts. This provided the capability to investigate the transition from the initial branding base to a more precise and focussed eating quality outcome.

Many detailed discussions and workshops were held with the marketing team to discuss and develop the concept, understand the existing supply and branding practice, and the philosophy driving the desired transition to a new eating quality focussed offer.

Birkenwood were provided access to production data for each of the 5 plants including the AUS-MEAT cipher, Product Specification codes and MSA grading inputs to enable extensive analysis on a carcase and cut basis. Initial analysis required the calculation of an MQ4 value for each of the 39 MSA model cuts and used as a base for evaluating eating quality distribution within existing Boning Groups and cipher based sort groups together with population subsets such as grass or grain fed, HGP or HGP Free, high tropical breed content or British breed. An example distribution for MSA graded tenderloin is displayed in Table 2. It is apparent from Table 2 that cipher based sorts had essentially no relationship to eating quality, indicating that cipher was not useful as a branding criteria.

Table 2. No of tenderloin cuts by MSA MQ4 score within cipher and feed type

		TENDERLOIN - CUT COUNT BY MSA SCORE																														
	Cuts Total	MSA 3*					MSA 4*													MSA 5*												
		55	59	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
JANUARY																																
YGGF	368												2	26	56	68	90	96	110	132	130	76	50	16	6	10						
GFYG	2742									134	438	444	358	320	306	312	220	114	70	20	6											
YP GF	20																		2	6	4	4	2	0	2							
Total Grainfed	3630	0	0	0	0	0	0	0	0	134	438	444	360	346	362	380	310	210	182	158	140	80	52	16	8	10	0	0	0	0	0	0
YG	768									4	12	30	58	84	148	118	34	4	30	42	58	50	66	16	8	4	2					
YP	2666									4	16	22	26	46	58	54	34	80	184	402	642	602	324	108	40	16	8					
S	968									30	90	96	126	132	114	88	76	66	46	34	36	22	10	2								
C	4																			4												
B	0																															
Total Grassfed	4406	0	0	0	0	0	0	0	0	38	118	148	210	262	320	260	144	150	260	482	736	674	400	126	48	20	10	0	0	0	0	0
TOTAL MSA	8036	0	0	0	0	0	0	0	0	172	556	592	570	608	682	640	454	360	442	640	876	754	452	142	56	30	10	0	0	0	0	0
Ungraded	1718					16	108	348	606	416	16	14	12	4	6	8	2	12	24	32	22	46	8	10	4	4						
TOTAL GRADED	9754																															
FEBRUARY																																
YGGF	1950													12	42	126	166	240	258	284	224	250	166	118	44	14	6					
GFYG	10506									244	1290	1576	1638	1450	1226	1102	768	534	348	194	112	16	4	4								
YP GF	54															2	2	4	16	14	6	4	2	2	2							
Total Grainfed	12510	0	0	0	0	0	0	0	0	244	1290	1576	1638	1462	1268	1230	936	778	622	492	342	270	172	124	46	14	6	0	0	0	0	0
YG	2742									4	72	170	280	292	394	234	210	154	230	248	262	128	44	14	4	2						
YP	7362									18	76	84	84	138	182	176	320	594	906	1296	1310	1054	628	300	136	36	18	2	4			
S	1750									42	172	148	174	256	202	156	152	118	82	96	74	48	24	6								
C	4														2	0	0	0	0	0	0	2										
B	0																															
Total Grassfed	11858	0	0	0	0	0	0	0	0	64	320	402	538	686	780	566	682	866	1218	1640	1646	1232	696	320	140	38	18	2	4	0	0	0
TOTAL MSA	24368	0	0	0	0	0	0	0	0	308	1610	1978	2176	2148	2048	1796	1618	1644	1840	2132	1988	1502	868	444	186	52	24	2	4	0	0	0
Ungraded	3794		2	2	12	18	154	512	942	1134	148	68	80	54	42	44	54	104	104	120	82	72	28	16	0	2						
TOTAL GRADED	28162																															

The very poor relationship of dentition and MQ4 is further illustrated in Fig. 2 which presents a large volume of MSA striploin data with actual consumer scored MQ4 for tested striploins within dentition categories. This emphasised the futility of using dentition based ciphers as a means to deliver consistent consumer cooked meal outcomes.

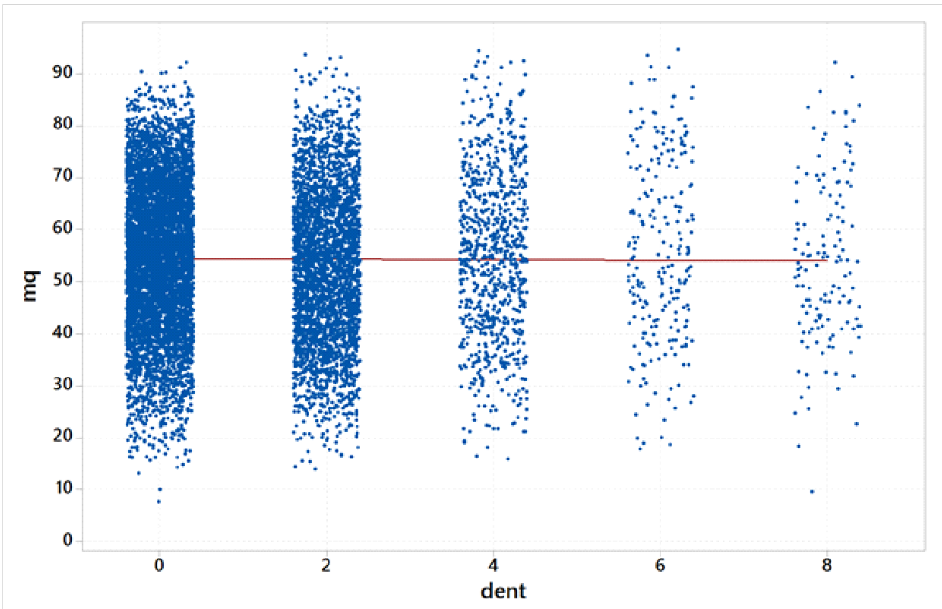


Figure 2. Observed MQ4 score by dentition category for 12,460 carcasses. (source Watson 2020)

In contrast Fig. 3 presents the relationship between ossification and MQ4 for the same dataset illustrating the prediction improvement that might occur with ossification being used as a component of prediction equations rather than dentition.

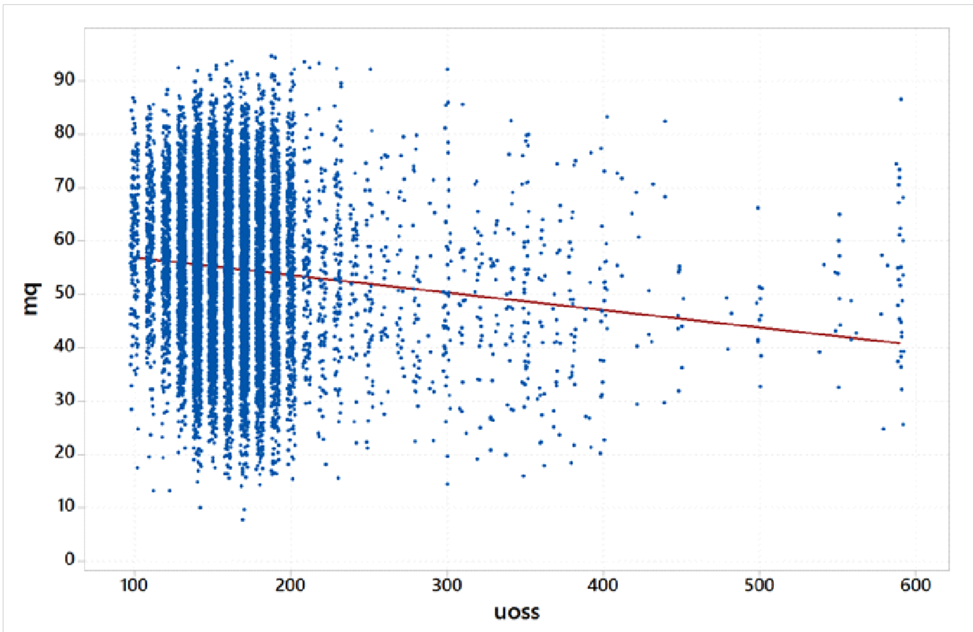


Figure 3. Observed MQ4 score by ossification category for 12,460 carcasses. (source Watson 2020)

Raw and calculated data was downloaded from the system with extensive further analysis conducted in Excel. MSA model adjustments for cooking method and ageing were also evaluated and discussed with the marketing group due to the impact on MQ4 values and related cut harvesting. Each cut had different characteristics due to differences across cooking methods and or the predicted improvement with ageing. For example, while striploin MQ4 increased considerably with ageing, tenderloin did not; while cube roll had very similar MQ4 when grilled or roasted, rump muscles improved considerably when roasted rather than grilled.

These insights were used to develop the basis for the initial branding strategy. ***It was agreed that cuts should be allocated to brands on the assumption that they would be cooked by the highest rated practical cooking method*** so that a rump would be sorted on the basis of its roast MQ4 whereas a chuck would be sorted on the basis of slow cook and tenderloin on grill. It was also agreed that ageing periods used to determine sorting would be related to the ageing potential so that tenderloin would be assessed at 5 days aged whereas striploin would be assessed at longer ageing, with the period extended where advantageous to achieve a superior cooked outcome. These criteria would also result in the carton label being a recommended use; roast this rump for best results, and an implied product usage caveat of "we guarantee the meal outcome if you roast but cannot guarantee the same outcome if you grill". The sales team however could also be empowered by knowledge of what the expected difference might be.

It was agreed that the marketing team should transition to being expert advisors rather than purely sales agents, aiming to deliver a desired meal outcome to customers, often via a range of alternatives; the customer should rely on expertise to deliver an outcome rather than be expected to understand the meat science and develop buying specifications that they hoped would deliver.

Initial discussion also determined the then limited range of cuts actually packed under an MSA grade. It was agreed that the initial stage should only assign carcasses to brand based boning runs on the basis of these, thereby removing the possibility of carcasses failing due to some other cut in an MSA Boning Group. A further critical decision related to whether brands should strictly align with MSA grades or be based on alternative MQ4 defined ranges and as to whether settings should be identical for all cuts within a brand or be cut specific.

Further analysis of MQ4 distribution for each cut and across each of the 5 plants established the harvested MSA grade proportions from existing data. This indicated that branding options and volume would be severely constrained by strict MSA grade adherence due to the large proportion of many cuts falling within a single 3* grade, inhibiting segregation.

When evaluated closely it was apparent that the MSA Boning Group table essentially applied a constant MSA 3* @ 5 days aged (46 MQ4 point) minimum setting to over 75% of all cut settings across the Boning Group categories, essentially an MSA pass/fail system allowing for no segregation within the MSA category for the majority of cuts.

The marketing team recommended a structure that allowed a desired percentage of each cut to be allocated to alternative MQ4 based categories that could underpin brands. This recommendation was adopted for all future work.

An initial simplified sort basis was developed utilising the accumulated data and based on the agreed principles. The proposed plan utilised only 8 cuts, two of which, rostbiff and shortloin, were alternative forms of others. Sort planning was designed to accommodate two alternative customer and plant based outcomes.

Practical application within the marshalling area and boning room was discussed extensively with production staff and wherever possible settings adopted that enabled product to be packed under common codes across the two programs. MSA labelling requirements were also discussed in detail with the MSA label statement required to apply to the MSA grade format. The MSA label statement designated the lowest possible MQ4 for a cut packed within the specified grade. This meant that in some instances the actual minimum brand based score exceeded the MSA statement, for example a 55 MQ4 minimum setting being substantially above the 46 MQ4 MSA 3* threshold.

It is noted that a common tenderloin setting was adopted with MQ4 as a grill just above MSA 4* at a minimum 5 day aged. The same standard was applied to butt fillet, only packed for the customer category but able to be readily interchanged as a full tenderloin. Further differentiation was adopted in the cube roll to accommodate customer specification of MSA 3* at 5 or 14 days ageing and to create two quality bands for use in branding. The highest H1 setting exceeded both customer settings, again providing production flexibility. The striploin settings provided two customer specific settings but designated additional ageing for company branded product to increase the MQ4 based consumer experience. This also recognised the high proportion of chilled product exported and consequently always aged beyond 28 days. The rump settings again display alternative customer specifications as grill and company settings as roast. Surplus product with customer settings readily translated to superior outcomes under the company roast appraisal. In contrast a single chuck setting was adopted reflecting current marketing under a single description with a slow cook base.

These considerations enabled MSA product to be packed under common codes across many cipher based boning runs. As a large proportion of secondary cuts were packed and marketed under cipher such as YG, PR or S there was an inherent production conflict in boning on the basis of MQ4 based outcomes as all non MSA cuts would be downgraded to the lowest cipher in a run.

Initially the intention was to utilise Birkenwood software to directly grade in the chiller with ruggedised tablets adopted to interact directly with the cloud system. Slaughter floor data was updated each evening to provide required grading inputs prior to the additional entries during grading. The cloud system calculated all MQ4 scores, checked each body against the settings and transmitted the highest possible sort group.

The initial trial established operational practicality and also provided proof that substantially higher volumes of key cuts could be harvested when the Boning Group restrictions were removed.

3.2.4 Expansion of brand based application

Extensive analysis followed the introduction of Birkenwood derived settings and packing of key MSA cuts on the basis of their individual MQ4 value rather than the MSA Boning Group of source carcasses. These analyses utilised extensive data evaluating monthly MSA production at each plant within grass and grain fed production.

Analysis was expanded to all 39 MSA model muscles together with consideration of cook type and ageing potential. After agreement of a standard cook type and ageing days for each muscle – and from muscle to cut – distributions for each monthly subset were created and accumulated to company by month and plant by year summaries.

Once a consensus was reached on draft settings the number of cuts by plant by month was input to further analysis that estimated cut weights utilising monthly average body weights for grass and grain by plant extended by standard yield %. Settings were workshopped extensively with marketing and production personnel to ensure that the required sorting could be achieved within plant limitations and met marketing aspirations.

These numbers were further extended by alternative pricing scenarios across the quality bands to generate revenue calculations. Pricing alternatives included estimated pricing by sales staff and current pricing, with an assumption that undifferentiated MSA product pricing would relate to Good, with % increments for the new Better and Best categories.

The revenue calculation process was also repeated for the current MSA Boning Group based production and compared to the proposed implementation plan.

On the basis of these analyses the plant PBR (Plant Boning Runs) were further developed to include more cuts and to facilitate more accurate eating quality distribution within key brands. The successful introduction provided assurance that a more sophisticated MQ4 based approach could be practically applied commercially across the business.

3.2.5. Advanced application utilising a new MSA model and plant adoption

The pending introduction of an entirely new and radically extended MSA V2.0 model in 2020 created further opportunity and some associated challenges. Base model changes resulted in significant differences to some cut estimates, a rebalancing of bos-indicus impact on grading results, additional cut and cooking method options and the ability to further extend ageing to 50 days on all cuts other than tenderloin, which was extended to 40 days. The more accurate estimate of bos-indicus MQ4 impact through hump height rather than TBC% model input upgraded many cattle with lower bos-indicus content that had previously been graded as "X" under the previous model. On the other hand reduction in ageing rates, to 0 for tenderloin, created challenges with reduced estimates for some cut x cook x ageing options.

Accordingly, analysis was approached from "a clean sheet of paper" to fully adjust to the new model outcomes and to proceed in close consultation with the marketing team with the opportunity to coordinate the new model introduction with refined brand based settings and provenance criteria.

An important fundamental move away from dentition based segregation to an *EQG* cipher that supplanted the traditional ciphers provided considerable scope for simplification in carcase marshalling and reduced boning room changeovers. While traditional ciphers were still required for some markets their utilisation was substantially reduced and consolidated, mostly to 0 to 6 and over 6 tooth categories.

As the new model also required modification to the Birkenwood software a major upgrade was commissioned to further improve functionality. Principal changes included the ability to run either or both MSA models, the addition of the new cut and cook methods related to V2.0, the introduction of "Production Plans" which enabled sophisticated specification of differential yield and pricing assumptions for cuts within each plan and carcase selection that included provenance and other non MQ4 based criteria to select populations for PBR assignment. Processing speed was also substantially increased, data loading routines simplified and reporting functions expanded.

The new development also coincided with the IT systems moving to an Amazon cloud based environment which included migration of the Birkenwood system and alternative access protocols. An allied Birkenwood software development was initiated in conjunction with the IT and analyst teams to calculate and provide detailed MQ4 scores for all cuts from all MSA graded carcasses that could be directly accessed by the analysts. An agreed file structure was developed and automated procedures instituted to upload batch data by IT to Birkenwood, check all fields, report any issues, calculate specified cut x cook x ageing MQ4 values and return these to the IT system where they could be accessed by Tableau or other tools. The base file of MSA model inputs and additional data related to livestock, marketing criteria and animal cost was retained within the Birkenwood site within the AWS cloud.

These refinements allowed detailed and extensive analysis at a more sophisticated level than was previously the case and greatly improved efficiency through automated rather than manual Excel interaction.

As a starting point 24 months of prior data for the 5 plants were processed through both the old and new MSA models to enable comparison. Data subsets of high and low bos-indicus cattle, HGP and HGPFRE, grass or grain fed, breed and plant specific brand based categories were also produced. These extensive analyses provided a thorough understanding of the impact of model change and many nuances relating to livestock and regional variation. Further input was provided from the marketing and sales team who were consulted regularly and intensively to workshop potential approaches and brand related objectives.

Following this essential background analysis all cut x cook x ageing criteria were revisited to establish optimum cut based combinations that could be incorporated in revised PBR. Individual monthly plant based analysis with multiple iterations of potential PBR settings were tested through the software to examine resulting cut quantities. These were also run across plants for brand criteria such as Angus, grainfed, grainfed and Mb 2, and natural categories. As a general principal PBR differentiation required a 7 MQ4 point difference or greater to justify additional PBR categories. Where a 7 point difference wasn't practical a lesser number of settings for those cuts were made constant within multiple PBR to enable packing to common codes across PBR based boning runs. It was agreed with marketing that MQ4 settings for all cuts should be common across grass and grain fed categories for simplicity and to facilitate "packing down" under common codes where feed type wasn't specified.

A structure of 5 PBR including up to 43 different cuts was developed that provided distinct quality segregation and high levels of cut capture. While side boning created inherent challenges and limitations to accurately packing each individual cut in a correct MQ4 specified category, extensive work and re-running of the production plans resulted in acceptable segregation. Fine adjustment was made to ensure that low value cuts were unlikely to fail first by reducing their cut-offs below the theoretical ideal value whereas priority high value cut settings were established "close to the line" and in combination to harvest the highest number possible within the higher PBR. The highest level PBR 1 was created for the 36˚South brand category with PBR 2 catering for a further premium brand tier. Where practical many cuts shared common settings across PBR 1 and 2 to enable common product code and packing. At the lower end the PBR 4 settings represented capture of most cuts at the MSA threshold 46 MQ4 setting. When all cuts were set at 46 a number typically exceeded this minimum but were "lost" due to others causing the carcase to fail (Ungrade). The PBR 5 category provided a vehicle to capture the "lost" cuts from PBR 4 by reducing the number of cuts in the PBR. PBR 5 settings were set identical to PBR 4 to enable both to be packed under common codes.

The PBR categories also provided a useful base for categorising cuts destined for further processing, including value adding. By supplying from a set PBR, including PBR 4/5 and cuts failing PBR 5, a more consistent raw material could be generated and then consistently improved by targeted value adding activity.

Once preliminary draft PBR settings were developed a heavy focus was placed on simplifying individual plant application while still expanding the number of cuts able to be packed under an MQ4 based structure. For cuts with reduced MQ4 range common MQ4 settings were adopted in adjacent higher or lower PBR to enable common codes and packing. This was also extensively adopted between the premium PBR 1 and PBR 2 where only a few key cuts differed significantly. For some cuts common MQ4 values were adopted at different ageing days with PBR providing a common consumer meal outcome after ageing. In concept the longer aged product could be prioritised for export shipment. The expanded use of the EQG cipher assisted in reducing carcase sorting prior to boning and reduced the challenge of packing secondary cuts that were to be packed under traditional ciphers.

The historical production data indicated significant differences in PBR distribution across plants with the southern plants heavily weighted to the upper 3 PBR and the northern plants toward the lower 3. This indicated that practical application could largely be reduced to 3 PBR within each plant, with the small number of carcasses above or below the selected 3 PBR being packed down as needed or, where numbers justified, the occasional use of a fourth PBR.

These and later refinements were workshopped extensively with the production, systems analysis and marketing teams over several months and evaluated on live weekly data to compare with the current output under the old MSA model. Daily production was also modelled across plants using actual daily data to determine the number of boning room changeovers, the volume within each and potential pinch points in marshalling. Once agreed, the settings were then transformed to MSA PBR inputs and related carton labels.

The new model and final PBR structure were commercially applied from September 1st 2020.

This changeover represented a huge developmental effort and substantial cultural and physical change, evolved over years but implemented across the business at a common time. To assist marketing and sales staff in providing high quality customer advice based on a thorough understanding of the refreshed branded product offer a detailed marketing manual was developed. The manual provided an overview of the base science and principals with support material for each cut offered including adjustment between the recommended and other cooking methods, impact of ageing and potential substitution by other muscles of similar performance.

3.3 Focus Area 3 - Value adding to enhance eating quality and customer value

The extensive data analysis conducted to provide a base for both VBM and branded program development provided detailed eating quality statistics for each muscle/cut portion contained within both MSA models together with weight estimates. This data was further categorised by month and grass or grain within plant and tracked over 5 years. Clear plant differences relating to cattle supply were evident and further reflected in the MQ4 distribution of muscles/cuts.

As the branding program and related PBR were developed and introduced the "catch all" PBR 5 in effect marshalled the majority of non MSA quality cuts within common boning room runs facilitating their collection and segregation. For some plants handling more cull cattle a high proportion of some cuts/muscles failed to reach an MSA 3* threshold. Potential value adding (VA) processes provided a possible mechanism to increase eating quality to an MSA compliant equivalence. These PBR 5 cuts were given primary consideration in VA development activity.

3.3.1. Potential for value adding interventions

Value adding of raw meat can take many forms including mechanical, chemical, temperature, either cold or through cooking, packaging and their combinations. Each can potentially interact with raw material quality. In the majority of studies conducted a controlled range of raw material collected from draft or agreed PBR categories was included to enable raw material quality, cut and treatment interactions to be evaluated.

The adopted principle was to measure VA treatment effects over an MSA predicted raw material MQ4 base reflective of PBR specifications. In principle a final commercial outcome could be delivered by an MSA based or equivalent VA Model with the raw material input defined by the standard MSA model output as depicted in Fig. 4.

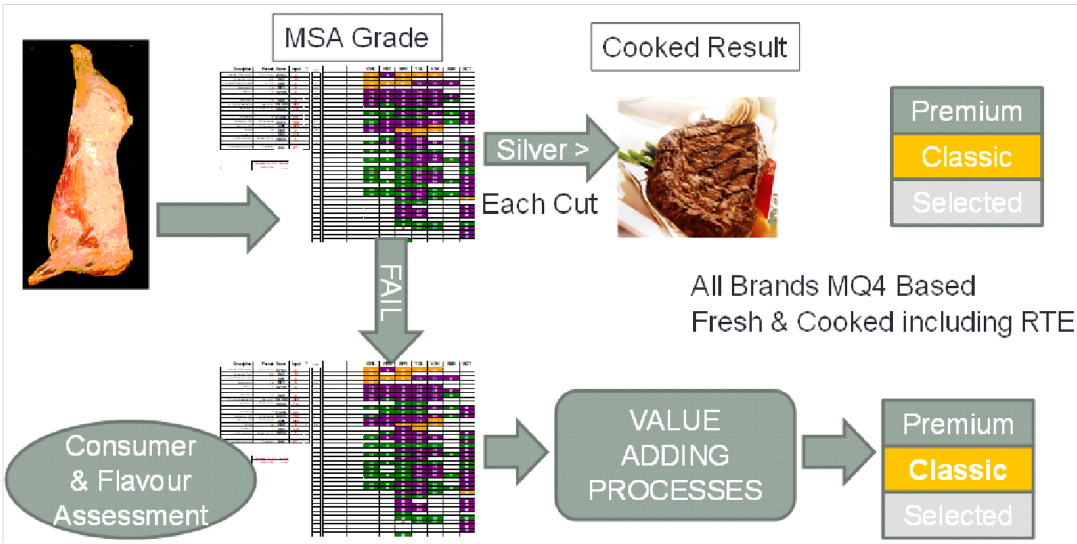


Figure 4. Conceptual view of a VA model utilising MSA defined raw material from PBR

In this figure it is assumed that only product that failed MSA grade specification would move to value adding but, while this might be a priority, the principle could also apply to enhancing premium brands.

Expansion of this base concept to incorporate the interaction of VA processes is presented in Fig. 5.

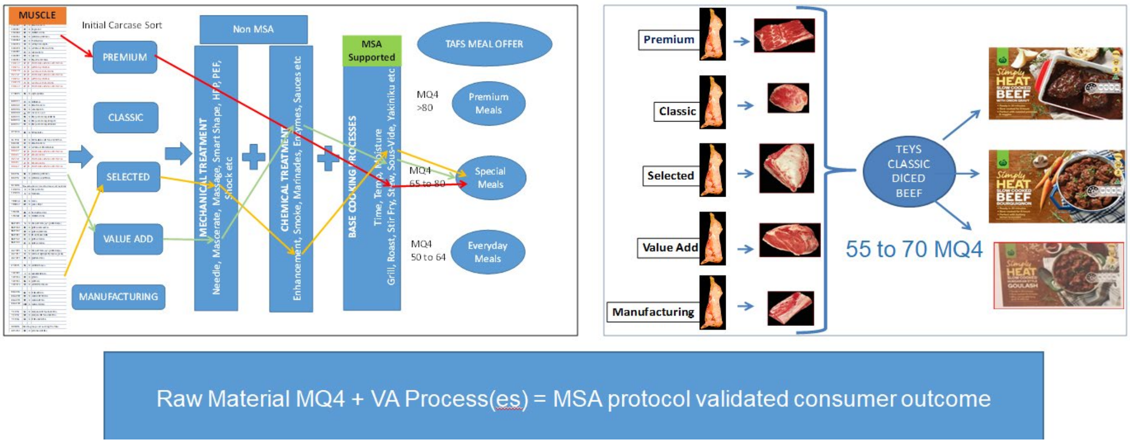


Figure 5. Conceptual interaction of raw material and VA processes to achieve common outcome

The "game changing" proposition within Fig. 5 is that a desired end result specified by eating quality (MQ4) can be created by multiple combinations of raw material, with 40+ muscles within 5 PBR to the left, then value added by single or multiple VA processes as indicated by the coloured arrows. This represented a radical change from industry practice where a specific cut and cipher, such as PR oyster blade, typified the raw material specification. In practice specifications of this nature restricted the ability to substitute other cuts in line with market price adjustments and further created inherent raw material variation.

The prospective matrix of raw material and VA interventions in contrast provided many alternative combinations to achieve a tightly specified consumer outcome and value point. The research program was designed to capture data that could be used to establish an initial matrix which could be extended over time creating significant commercial advantage.

An understanding of process was also fundamental to developing commercial application with Fig. 6 illustrating three potential outcomes.

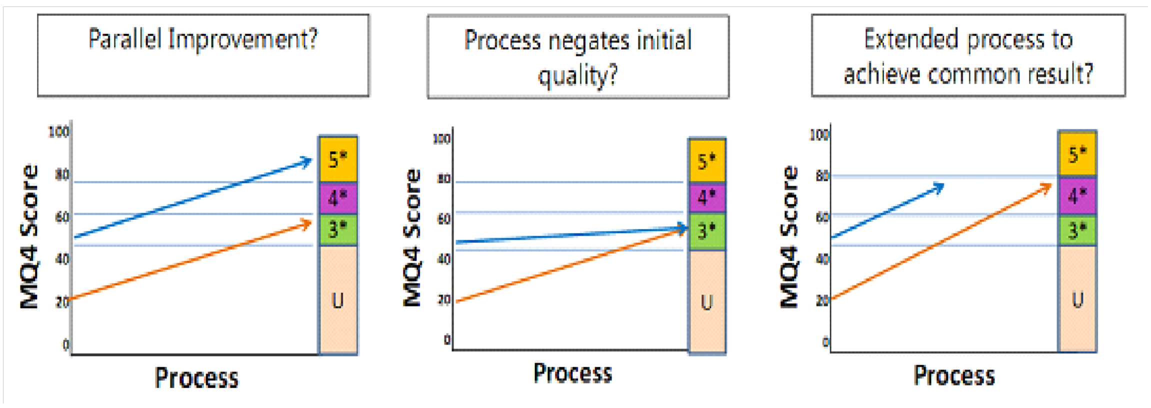


Figure 6. Potential product response to VA process application

As illustrated in Fig. 6, one possibility was that a VA treatment created an equal MQ4 improvement above the initial raw material so that the final VA products, while both improved, retained the same MQ4 difference as the raw materials. A second possibility was that any raw material difference was negated by the VA treatment, favouring use of lower quality or cheaper raw material, while the third option illustrates a position where a common MQ4 endpoint might be delivered from different raw materials by varying the treatment, for instance by alternate cooking time or different addition rates.

3.3.2. Experimental principles and standards

An adopted foundation principle was that untrained consumer evaluation would be utilised as the ultimate measure of all work conducted, supported where needed to gain further understanding of causative mechanisms by further laboratory processes. It was agreed that MSA consumer testing protocols would be utilised in all consumer testing to ensure consistency with the considerable base of accumulated MSA science and available data.

Where cooking and serving procedures were not within the existing MSA protocols new protocols strictly adhering to core principles were developed and made available to MSA for future work. These included development, in conjunction with Texas Tech University, of a Texas BBQ (TBQ) cooking method and related sliced, chopped and pulled serving forms together with procedures to compare product served hot in conjunction with paired product that was held in chilled vacuum packaging for a period and then re-heated.

Other cooking protocols developed in conjunction with MSA related to roast cooking in commercial combi ovens, sous-vide and reheating and serving of RTH retail product.

MSA project design principles regarding balanced presentation and replication were also incorporated into packaging projects that included consumer observation and scoring of visual appearance within a retail cabinet.

Further protocol development was conducted for flavour chemistry analysis using GCMS technology with the primary input from Dr Linda Farmer of AFBI and Dr Jerrad Lagako of TTU. These data were integrated with sensory results from the same samples and included cooking, enhancement and packaging project samples. An understanding of flavour perse and of flavour development mechanisms was regarded as particularly important for the VA studies as the addition of non-meat ingredients by injection or rubs was expected to modify flavour outcomes.

3.3.3. Value added marketing interaction

An essential component of the value added project development was continual liaison with management who provided valuable knowledge built from experience in regard to the installed equipment at their disposal and industry value adding knowledge. This was augmented by processing and marketing personnel who advised on product priorities and potential for commercial exploitation.

A number of workshops and seminars were held at different company sites, to develop VA research priorities, establish trial protocols and to discuss outcomes, including scope for commercial application and priorities.

3.3.4. Individual projects conducted

A number of major VA projects were conducted through related project codes in addition to extensive additional work delivered within the primary project code to integrate findings of contributing projects into a strategic value adding commercial proposition. Major areas of activity are described below.

3.3.4.1. Enhancement study at a cooking facility

A complex VA study (P.PIP.0503) was conducted at a processed meat facility. This followed earlier MSA exploratory enhancement work conducted at TTU utilising Australian and USA striploins and rumps, and a phosphate based enhancement mix provided by Darden USA (Garmyn *et al.*, 2012). Favourable results from this trial had been replicated with Australian consumers with this work also finding a local Kiwifruit based material similarly effective. Further trials where kiwifruit injection was combined with post injection ageing (McGilchrist *et al.*, 2013) and a UNE study evaluating a mushroom extract (Geesink *et al*., 2017) were evaluated in developing the VALUE ADD study. These trials all demonstrated tenderness improvement as assessed by consumers but indicated some potential issues with severe flavour problems with the mushroom treatment and potentially decreased MQ4 scores with ageing post injection. These trials included striploin (*M.longissimus dorsi*), rump (*M.gluteus medius*) and outside flat (*M.biceps femoris*) but were not structured in regard to initial raw material.

A series of workshops were held with the meat processing establishment management to discuss the project objectives and prioritise cuts and processes. It was agreed that initial work should focus on high value cuts and on processing that could be achieved with existing equipment. Striploin, rump and oyster blade were identified as priority cuts. Existing processing provided basic processes to mechanically tenderise, to inject, to massage and to cook industrially. After discussion, it was agreed that the impact of combinations of injection and tenderising were expected to be much greater than massaging leading to this process being left out of the initial trial. The 5 treatment options elected were:

1. A phosphate solution at 10% injection.
2. A kiwifruit extract solution at 10% injection.
3. A ficin (fig) extract solution at 10% injection.
4. The kiwifruit treatment plus needle tenderising.
5. The ficin treatment plus needle tenderising.
6. An untreated control.

The study considerably broadened the prior experimental scope by including a comparison of phosphate, kiwifruit and ficin (proteolytic enzyme sourced from an American wild fig) based enhancement products, needling in addition to kiwifruit and ficin plus a non-treated control combined with a structured MQ4 based range of raw material. To best replicate commercial application it was agreed that the meat products factory should be utilised to prepare the trial product. It was agreed that the primary commercial target was for steak cuts from the rump muscles and that grill and roast were of interest for the striploin. As oyster blade was being extensively utilised in RTH (ready to heat) pre-cooked products it was elected to test these samples, with identical prior treatment, in a pre-cooked and then re-heated form.

The entire kill of one plant on May 6th 2016 was MSA graded and assessed to provide a range of product for trial selection. The kill included grass and grain fed cattle including EU grain fed and non MSA eligible manufacturing carcasses. MSA grading files were evaluated by Birkenwood software to assign each of the 5 grades. The grade results (Best, Better, Good, Value Add and manufacturing) were then used to select carcasses for cut collection and additional measurement.

Striploin, rump and oyster blade primals were collected from 59 bodies with the 236 cuts transferred to the meat products plant for 21 days ageing prior to fabrication and treatment. Linkage between the original carcase number, side, kill and grading data was established by MSA collection software which was also used to produce control files for subsequent treatment at meat products plant and to upload data to a database.

All collected cuts were prepared for value adding on May 26th and treated on May 27th. Control files were created through MSA software to allocate treatments to positions within cuts and across right and left sides. In total 8 samples were designated for striploin (STR045) from one carcase, 2 for rump cap (RMP005), 2 for the 1/3rd portions of the rostbiff (RMP231) and 4 portions from the larger 2/3rds portion of rostbiff (RMP131) and 4 from the oyster blades (OYS036). Treatment allocation was rotated to balance side and position within cut. The primals were denuded, separated into single muscles and portioned according to the designated cooking method. All portions to be treated were firstly weighed. The value adding processes were then applied with each treatment run as a continuous batch to provide a smooth work flow. The preparations used were:

- Phosphate blend EP#20803
- Kiwifruit blend EP#20802
- Ficin blend EP#20801

Each was mixed to the manufacturers specification and a number of test portions processed to calibrate the addition rate. A Garos GSI 620 combi injector tenderiser with 2 x 72 needles, each with 4 ports was used for the injection treatments. A Ross needle tenderizer was used for the two tenderising treatments. Individual sample ID and treatment allocation was maintained by laminated uniquely identified tags placed with the sample in vacuum bags prior and post injection and needling, with strict control of order into and from the equipment. After treatment each portion was again weighed and then further processed following MSA protocols to produce 1,180 consumer test samples. While roast and reheat samples were packed as “blocks” the grill samples were fabricated from the treated portion utilising a cutting jig to produce 25mm thick slices, further trimmed to create 5 small steak portions. Each of these were wrapped in freezer wrap prior to packing the set of 5. Each final consumer test sample provided sufficient material for evaluation by 10 consumers.

An additional flavour portion was fabricated within each consumer sample for later shipment to AFBI in Belfast for flavour chemistry evaluation.

A Multivac 140 thermoform machine was used to pack all samples using flexible top and bottom webs sealed at 140˚C. Laminated unique identification tags were packed within the grill and roast pouches with numbered stainless washers used for the oyster blade reheated samples to ensure ID after cooking in the thermoform pouch. Table 3 presents the number of consumer samples fabricated within cut, cook and treatment.

Table 3. Number of consumer samples fabricated by muscle, treatment and cook type

COOK LABEL	CUT					TOTAL	COOK	GRL	RST	Notes
	OYS036	RMP005	RMP131	RMP231	STR045					
CONTROLS - NO PROCESSING										
GRL		19	39	20	90	168		168		GRL cut & packed as MSA sensory without processing (controls)
RST	87				87	87			87	**RST** cut & packed as MSA sensory without processing (controls)
RST	39					39	39			Oyster Blade control - cooked without treatment
						294				
Phosphate 10%										
P10		20	39	20	30	109		109		Phosphate 10% - Cut & packed as **GRL** after treatment
P10	39					39	39			Oyster Blade - cooked after treatment
RP1					29	29			29	Phosphate 10% - Cut & packed as **RST** after treatment
						177				
Kiwi 10%										
K10		20	39	20	30	109		109		Kiwi 10% - Cut & packed as GRL after treatment
K10	39					39	39			Oyster Blade - cooked after treatment
RK1					29	29			29	
						177				
Kiwi 10% and Tenderised										
K+T		19	40	19	30	108		108		Kiwi 10% & Tenderised - Cut & packed as GRL after treatment
K+T	39					39	39			Oyster Blade - cooked after treatment
RKT					29	29			29	Kiwi 10% & Tenderised - Cut & packed as **RST** after treatment
						176				
Ficin 10%										
F10		20	40	19	30	109		109		Ficin 10% - Cut & packed as GRL after treatment
F10	40					40	40			Oyster Blade - cooked after treatment
RF1					29	29			29	Ficin 10% - Cut & packed as **RST** after treatment
						178				
Ficin 10% and Tenderised										
F+T		20	39	20	30	109		109		Ficin 10% & Tenderised - Cut & packed as GRL after treatment
F+T	40					40	40			Oyster Blade - Ficin 10% & Tenderised - cooked after treatment
RFT					29	29			29	Ficin 10% & Tenderised - Cut & packed as **RST** after treatment
						178				
						TOTALS	**236**	**712**	**232**	**TOTAL 1180 sensory test samples**

The oyster blade derived products were cooked for 8 hours at 80˚C in a Vemag industrial oven overnight on May 27th to align with the 22 days from slaughter to final processing for other treated and control product. Roast and grill samples were transported to UNE, frozen and allocated to consumer test "picks" in accordance with MSA sensory testing protocols (Anon 2008).

Each pick represented 60 untrained consumers who each evaluated 7 product portions, the first a common mid quality "link" sample and the remaining 6 being one from each of 6 products created by the link and 5 treatments. MSA software utilised a 6 X 6 Latin square sequence to control serving order to ensure each product was served an equal number of times (5) in each order and before and after each other product. Every sample was evaluated by 10 consumers.

The grills were cooked at the sensory venues utilising a Silex S-143 3 phase clam shell grill with cooking controlled by adherence to a timing sheet and count up timers following MSA grill protocol (Anon 2008). The MSA protocol was also followed for the roasts cooked which were cooked in a combi oven set to dry heat at 160˚C until reaching an internal temperature of 65˚C after which they were rested, trimmed, fitted to small stainless steel keepers with cutting slots at 10mm intervals and transferred to bain maries until served. The pre-cooked oyster blade samples were removed from their cook packaging, blocked to fit a roast keeper which was placed in a 1/9th bain marie pan, lidded with aluminium foil and heated for 40 minutes in a fan forced oven set to 190˚C in accordance with the retail label cooking directions. On removal, the pans were placed in bain maries set to 50˚C and the foil replaced by stainless steel lids. After transfer to the bain maries serving of roasts and reheated product followed MSA protocol (Anon 2008).

The consumer questionnaire data was double entered to ensure accuracy and then combined with the animal, slaughter and grading data for statistical analysis.

To test all trial product 18 grill, 5 roast and 7 reheat picks were produced and evaluated by 1,800 consumers. All except one grill pick were conducted by TastePoint in the greater Melbourne region with the final grill pick conducted at Head Office with staff, recruited as consumers. This was regarded as a valuable exercise in acquainting staff with the sensory procedures used and as further involvement in the research activity.

3.3.4.2. Evaluation of potential "clean label" enhancement solutions

While enhancement with the traditional phosphate and more recent kiwifruit-based products produced impressive improvements in tenderness there were indications that consumers judged the products to be "different" to natural meat and too often have a very salty taste. With greater consumer attention to labelling and food additives a study was planned to evaluate potential "clean label" alternatives that might also deliver more natural taste and texture.

Following discussion with an experienced older chef and culinary educator, Louis Ferguson, the traditional practice of collecting all the juices, etc, after cooking and then using reduction to control flavour intensity was developed further. The research question developed was "**could a natural beef stock be utilised as an enhancement medium**" with the potential to retain or modify a natural beef flavour and texture, with some possible tenderising through the addition of this liquid base.

Texas Tech researchers and plant managers were also consulted to workshop a range of potential enhancement products. From this a research design was created to compare several products with the traditional phosphate approach and untreated controls. It was agreed that the study be initially conducted at TTU due to their experience in enhancement and well-equipped laboratory, which included commercial scale injection equipment. It was further agreed that the study should focus on traditional "problem cuts" that had high MSA failure rates. These were identified as eye rounds, knuckles and striploins from lower quality cattle.

To ensure potential interactions between treatments and initial raw material quality were captured a tightly structured cut collection plan was developed which included grass and grain fed cattle from the top 4 PBR categories and grass-fed manufacturing cow product from the lowest PBR 5.

As this collection base required considerable effort and plant disruption it was agreed that the same carcasses be used to source cuts for two other projects relating to packaging and appraisal of the traditional Texas smoked brisket cooking method, designated TBQ. The agreed carcase selection plan is displayed in Table 4.

Table 4. Planned carcase collection by feed and PBR category for three research studies.

Projected Carcase Quality	FEED	No. Head		
Premium MSA Quality	Grain	9	Striploins and Cube Rolls utilised in packaging project	
	Grass	9		
High MSA Quality	Grain	9		
	Grass	9		
Base 3* MSA Quality	Grain	9		
	Grass	9		
Ungrade MSA Quality	Grain	9		
	Grass	9		
Manufacturing non MSA Quality	Grass	18		
	Total	**90**	Packaging	**54**

It was agreed that cuts from both sides of each carcase would be collected to provide sufficient material for the planned project activities.

The logistics for these collections were challenging on many fronts. A final action plan was developed in conjunction with plant management with extensive workshopping to establish practical procedures that allowed sufficient time to identify bodies within each category after grading and before final marshalling for boning, retain accurate individual cut ID and reliably collect a large number of cuts within the boning room where cuts were removed on multiple lines rather than sequentially, as occurred with side chain layouts. Further complications included accurate segregation of cuts, packaging and labelling to ensure product was correctly allocated to frozen or chilled storage and despatched to either USA or Australian locations.

The initial process run was on Friday October 20th, 2017. The plant programmed the kill to include a wide range of grass and grain-fed cattle with the plant arranging to marshal and MSA grade over 500 head on the Saturday morning for selection. This provided sufficient time to select trial bodies, take additional measurements and marshal into boning runs. The plant grading results were processed through Birkenwood software to allocate each body to brand based quality categories. Birkenwood and MSA staff then assessed bodies within each category and selected those for the trial collection.

To add value to the work the selected carcasses were also assessed by the MIJ (Kuchida) camera, Frontmatec hyperspectral and MEQ probe together with Hunterlab and NIX colour measures and full MSA grading. Carcasses selected for trial collection were identified with large coloured and laminated tags and marshalled onto common rails by plant staff prior to boning. To facilitate collection in the boning room further tags were then pinned to all cuts to be collected.

Table 5 lists the primal cuts collected from both sides of each carcase and the subsidiary muscles available for study. The collection process required 54 people, assembled from research personnel from MSA, Birkenwood, CSU and UNE, and including senior QA staff and supervisors who allocated people to positions and controlled the collection process. People were allocated to positions to ensure tags were not lost and remained with the cuts throughout the boning and slicing processes including retaining ID at band saw locations. Others were positioned at each bagging station to retrieve the stainless-steel pins used to secure the cut tags and to transfer the tags to within each primal bag. The cut tags were coloured to indicate frozen or fresh or further processed, UNE or TTU destinations. Further staff were located in the packaging area and checked final cut counts within destination.

Table 5. Cuts collected from all carcass sides.

Primal	HAM no.	MSA Code	Muscle
Short ribs	1691	INT037	M.intercostales externus and internus
		RIB041	M.latissimus dorsi
		RIB078	M.serratus ventralis thoracis
		BRI056	M.pectoralis profundus
NEB	2340	BRI056	M.pectoralis profundus
PEB	2330	BRI057	M.pectoralis superficialis
Cuberoll	2243	CUB045	M.longissimus dorsi et thoracis
Striploin	2142	STR045	M.longissimus dorsi et lumorum
Eye Round	2040	EYE075	M.semitendinosus
Knuckle	2070	KNU066	M.rectus femoris
		KNU098	M.vastus intermedius 2069
		KNU099	M. vastus lateralis 2068
		KNU100	M.vastus medialis

All the ribs and briskets were frozen after cut collection at the plants whereas the remaining cuts were stored and transported chilled. The cube rolls and striploins from the MSA compliant 54 head in the upper three categories were allocated to the packaging study and held in the chiller for a 14-day ageing period. All other cuts were sorted for delivery to either TTU in Lubbock, Texas, or UNE in Armidale for further processing and consumer testing.

This allocation related to carcase with cuts from both sides of 6 bodies of the 9 within each of the top 4 categories and 12 of the manufacturing allocated to TTU in addition to one side of each of the remaining 3 (6 for manufacturing) bodies in each. Cuts from the other side of the 3 or 6 bodies were despatched to UNE to enable an Australian:USA consumer comparison. This resulted in 150 primal cuts being shipped to TTU and 30 retained in Australia in addition to those set aside for the packaging study.

The outstanding assistance of plant managers and staff in successfully achieving this extremely complex activity was both essential and greatly appreciated.

On arrival at TTU in Lubbock, Texas, some 80 days after packing due to shipping and land transport delays in USA due to a blizzard, the frozen brisket and short rib product was stored frozen, and the chilled cuts fabricated for enhancement or control. Initial fabrication was to “blocks” of suitable form for subsequent fabrication to MSA consumer sample protocols after injection. Samples were prepared for grill, roast, and stir-fry cooking methods. The striploin, cube roll, eye round and the large knuckle cover, and centre muscles were prepared as grills and roasts with two small knuckle muscles (MSA codes KNU098 and KNU100) prepared for stir fry.

Complementary USDA graded product was also collected by TTU in Schuyler Nebraska on December 11th, 2017. Striploins, knuckles, and eye rounds were collected for the enhancement study in addition to briskets and ribs for further comparison in the TBQ cooking study. Cuts were selected from USDA Prime, Choice and Select quality grades and fabricated in identical manner to the Australian samples under Birkenwood supervision.

MSA and Birkenwood software was utilised to fully develop the VA design and assign treatments in a fully balanced manner to body, muscle, and muscle position within each treatment.

Treatments selected for comparison were:

1. Untreated control
2. Conventional phosphate. (Pentasodium Triphosphate – tradename CARFOSEL 408)
3. Natural beef stock (Swanson natural beef stock purchased at supermarket)
4. Sodium carbonate (Tradename - Prescribed for life)
5. Sodium bicarbonate (Tradename - Prescribed for life)
6. A natural potato starch (Modified food starch – tradename PenCling 530 – 0680402)

The control samples were processed into MSA protocol consumer samples and vacuum packed. Samples to be treated were injected in batches with a thorough clean of the injector between treatments. Test samples were injected to confirm the selected 10% injection rate prior to each batch. All samples were weighed raw and again after injection.

Table 6 details the mix rates for the injected material and final product composition.

Table 6. Enhancement liquid mix and final product addition rates

Phosphate		
	Percent	Weight
Water	92.5	10
Salt	3	0.3
STP	4.5	0.45
Total	100	10.75
Meat	90	1
Water	9.25	0.0925
Salt	0.3	0.003
STP	0.45	0.0045
	100	1.1

Flavor		
	Percent	Weight
Water	93	10
Salt	3	0.3
STP	4	0.4
Total	100	10.7
Meat	90.05	1
Water	9.25	0.0925
Salt	0.3	0.003
Flavor	0.4	0.004
	100	1.0995

Starch		
	Percent	Weight
Water	84.5	10
Salt	3	0.3
STP	12.5	1.25
Total	100	11.55
Meat	89.2	400
Water	9.25	37
Salt	0.3	1.2
Starch	1.25	5
	100	443.2

Sodium Bicarbonate		
	Percent	Weight
Water	94	10
Salt	3	0.3
STP	3	0.3
Total	100	10.6
Meat	90.15	1
Water	9.25	0.0925
Salt	0.3	0.003
NaHCO3	0.3	0.003
	100	1.0985

Sodium Carbonate		
	Percent	Weight
Water	95.5	500
Salt	3	15
STP	1.5	7.5
Total	100	522.5
Meat	90.3	20
Water	9.25	1.85
Salt	0.3	0.06
Na2CO3	0.15	0.03
	100	21.94

After injection the samples were fabricated into consumer samples following MSA protocol and labelled with the final Sequence and EQSRef codes to be carried through to consumer testing.

Consumer testing procedures were also in strict accordance with MSA protocol. Each pick included a controlled combination of cuts, treatments, and base raw material quality levels with both Australian and USDA sourced product. Treatment comparisons from individual cuts within a common body were principally tested within common picks to have comparisons within consumer groups. While all grill samples were fully consumer tested in 41 picks, utilising 2,460 Lubbock area consumers, roast and stir fry samples were held in frozen storage pending funding approval.

3.3.4.3. TTU Fajita enhancement project

North America have developed a large market for fajita meat sourced from Australian production. Typically, fajitas are prepared from secondary cuts including flank and diaphragm which provides an attractive marketing option. Preparation of fajitas typically involves either marination in home or prior commercial enhancement of some form. A Texas Tech student project was utilised to evaluate enhancement of fajita meat derived from 5 alternative muscles enhanced by vacuum tumbling with either a phosphate based or “clean” sodium bicarbonate brine and compared to non-treated controls. The project objectives included gaining an improved understanding of alternative muscles, the impact of enhancement and potential for “clean” labelling and the potential to market in a value added rather than raw form to capture revenue above the commodity raw material market.

Cuts were sourced over 4 days from 40 grain and 40 grass fed carcasses distributed over a wide quality range as indicated by PBR and displayed in Table 7.

Table 7. Number of head within PBR and feed type selected for fajita evaluation.

Grade	Grain	Grass
Best	9	10
Better	9	7
Good	17	4
Value add	3	0
Ungraded	2	19
Total	40	40

These were obtained from those selected for yield studies in a major ALMTech project which utilised measured yields to evaluate and develop DEXA technology. This provided an ideal opportunity to source the desired muscles across diverse carcase types, with the presence of TTU interns engaged in the yield measurement facilitating sample collection. Five muscles, displayed in Table 8, were collected from the right side of each carcass.

Table 8. Muscles collected for fajita evaluation.

HAM No	Trade Desc	MSA Code	Muscle
2002	Topside Cap	TOP033	*M.gracilis*
2204	External Flank Plate	TFL051	*M.obliquus externus abdominis*
2206	Internal Flank Plate	TFL052	*M.obliquus internus abdominis*
2210	Flank Steak	TFL064	*M.rectus abdominis*
2180	Thick Skirt	DIA092	*M .transversus abdominis*

Each muscle portion was vacuum packaged individually, identified by a uniquely coded label, and held in chilled storage at 0 to 1°C for 14 days before freezing at -20°C for transport to TTU. For this project TTU selected all available muscle portions from 14 of the grain-fed and 8 of the grass-fed bodies representing a range of PBR brand categories within each feed type as displayed in Table 7.

Processing and consumer evaluation was conducted at TTU. Muscles were thawed for 48 hr at 2 to 4°C before sample processing. After removing excess fat and sinew each muscle was halved, cutting parallel to the muscle fibres. Two of the 3 treatments (control, clean, phosphate) were assigned to each muscle with each rotated to achieve balanced pair comparisons. All muscle halves were weighed to obtain green weight. Control muscle halves were untreated. The distribution of final muscle portions after halving is shown in Table 9.

Table 9. No of head and sample counts by feed type, grade, and muscle

			Sample counts by muscle					
Feed type	**Grade**	**No Head**	**DIA092**	**TFL051**	**TFL052**	**TFL064**	**TOP**	**Total**
Grain	Best	3	6	6	6	6	6	30
	Better	3	3	6	6	6	6	30
	Good	5	8	10	10	10	10	48
	Value Add	3	6	6	6	6	6	30
Grain Fed total		**14**	**23**	**28**	**28**	**28**	**28**	**138**
Grass	Best	4	8	6	8	8	8	38
	Better	2	4	4	4	4	4	20
	Good	2	4	4	4	4	4	20
	Value Add	0	0	0	0	0	0	0
Grain Fed total		**8**	**16**	**14**	**16**	**1**	**16**	**78**
Total Grain and Grass		**22**	**39**	**42**	**44**	**44**	**44**	**216**

"Clean" muscle halves were enhanced with sodium chloride (NaCl; Morton Salt Inc., Chicago, Illinois), food grade sodium bicarbonate ($NaHCO_3$; Church & Dwight Co. Inc., Ewing Township, New Jersey), and water. The brine was prepared in 5°C tap water with 4.16 % NaCl and 4.00% $NaHCO_3$. Brine was poured over the muscles in the vacuum tumbler for a target pickup of 112% (111.68% ± 3.82) of fresh muscle weight. All muscles were placed in a vacuum tumbler (Koch Industries, Wichita, Kansas) and a vacuum (20 "Hg) was pulled. Muscles were batch tumbled at 10 RPM for 20 min. Samples were allowed to rest for 10 min and tumbled weight was obtained and recorded for each muscle half. Pickup percentage was calculated by taking tumbled weight divided by green weight, multiplied by 100.

Phosphate muscles were enhanced with NaCl (Morton Salt Inc., Chicago, Illinois), sodium tripolyphosphate (STPP; Carfosel 408, Prayon Inc., Augusta, Georgia), and water. The brine was prepared in 5°C tap water with 4.16 % NaCl and 4.00% STPP. Brine was poured over the muscles in the vacuum tumbler for a target pickup of 112% (111.59% ± 4.00) of fresh muscle weight. Muscles were tumbled as previously described for clean enhancement. Samples were allowed to rest for 10 min and tumbled weight was obtained and recorded for each muscle half. Pickup percentage was calculated by taking tumbled weight divided by green weight, multiplied by 100.

Regardless of enhancement treatment, a sample was obtained (weighing approximately 10 g) after treatment application and before vacuum packaging. This sample was vacuum packaged individually and frozen at -20 °C until analysis of final pH. All remaining muscle samples were vacuum packaged individually and held at 2 to 4°C. Samples were sorted into 1 of 6 testing days, and muscles were used in consumer sensory testing within 9 days of processing.

Consumer testing, arranged as 6 “picks” of 60 local area untrained consumers, was conducted at TTU. Each muscle sample was removed from packaging and weighed individually to obtain a raw weight. Muscles were cooked individually to 74°C on a George Foreman clamshell grill (Model GRP99, Spectrum Brands. Inc., Middleton, WI) with the lid closed and a plate temperature set to 218°C. Muscle temperature was monitored using a digital, instant read Thermapen thermometer (Model Mk4, ThermoWorks, American Fork, UT). Peak temperature and cooked weight were recorded and cooking loss percentage calculated. In addition, total cooking time was recorded. Muscles were rested for at least 3 min prior to slicing. Muscles were sliced into 13-mm strips perpendicular to the muscle fibres, and strips were cut in half lengthwise, resulting in strips that were approximately 5 cm long. Strips were transferred to pre-heated bain-maries with each sample placed in 1/9th steamer pans, with the lids carrying the unique sample EQSRef ID codes.

Consumer serving testing was conducted according to MSA protocols (Anon 2008), with previously described modifications for cooking method. Each consumer evaluated seven samples, including a first served “link” sample followed by 6 samples, each from a designated product arranged as grass- and grain-fed within control, phosphate and bicarb treatments. The serving order of the six test products was controlled by a 6 × 6 Latin square design ensuring that all products were presented an equal number of times in each serving order position and before and after each other product. The test products were selected from the five muscles that were or were not enhanced. The predicted eating quality score (MSA grade) was also used for selection and allocation into the consumer testing design. Those products were equally represented and evenly distributed among the 60 consumers in each pick sensory event. MSA software-controlled routines ensured that the samples from each individual muscle were served in 5 different order positions and within different subsets of 12 consumers within each group of 60.

Consumer data was double entered and cross checked to confirm line scale readings with the electronic file emailed to Birkenwood who processed the data and connected the sensory and demographic output with all preceding sample data for statistical analysis.

3.3.4.4. Meat colour, pH, dentition, and packaging study

Persistent producer and plant concerns relating to MSA failure due to meet colour above AUS-MEAT 3 and/or pH>5.7, principally in grass-fed bullocks, stimulated further investigation of these issues. Rod Polkinghorne in his role of investigating supplier complaints or concerns was asked to visit and observe procedures relating to a large-scale central Queensland producer. This included visiting the property to discuss pre-despatch procedures, observing mustering and truck loading, following the trucks to processing, observing unloading, lairage management and monitoring kill procedures. MSA grading was also observed the following morning and data analysed.

This produced the unexpected result that a moderate proportion of cattle with meat colour above 3 when graded had an ultimate pH below 5.7. Classic meat science regarded pH and meat colour as well correlated which was not the case observed. It was arranged with plant staff to identify and hold cube rolls from these cattle and to re-assess colour and pH some days later. These and some replicated observations on other cattle found that after a period pH and meat colour did move into an expected and correlated pattern. Clearly this finding indicated that there were fundamental issues relating to colour assessment at grading. It was evident that at least cube rolls from carcasses that failed at grading might readily pass the same criteria by the time they could reach retail display.

This added to concerns that producers and the company could be penalised based on failing meat colour specifications that would be compliant at retail.

A large-scale complex study was developed as P.PIP.0488 to systematically investigate this issue. It was elected to include a controlled range of dentition in the study to establish whether this might be interrelated as believed by some retail groups, and to concurrently observe potential changes in colour and pH with multiple primal ageing periods prior to retail cut fabrication and packaging. As retail packing include overwrap (OWP), modified atmosphere (MAP) and vacuum skin (VSP) forms these were also included in the design with untrained consumer observation of the packs in a retail cabinet display an important assessment method in addition to objective assessment of colour and pH at each production stage.

A target matrix of pH, meat colour and dentition was established to guide carcase selection and the entire plant kill on Monday September 7th, 2015, evaluated to select bodies within the matrix with priority to be given to grass-fed cattle. The matrix cells reflected expectations that there were unlikely to be bodies above 5.7 pH with meat colour less than 3, but likely to be a number with pH under 5.71 with meat colour greater than 3 which could be contrasted with others with both pH and meat colour outside MSA criteria. The target specified 6 bodies with pH below 5.7 in each meat colour score from 1C to 5 and a further 6 bodies with pH greater than 5.7 within meat colour scores 3, 4 and 5 for a total of 48 bodies. It was also noted that where possible an even distribution of dentition was desired within each cell.

The tight combination of criteria imposed severe time constraints on carcase selection due to the large number of bodies (over 500 grass-fed), and likely scarcity for some cells, to be reviewed prior to marshalling for boning. Commencing at 1:00 am company graders made an initial assessment of colour with MSA research graders following to assess pH and, where colour pH and dentition related to an unfilled matrix box, full MSA grade data. The quartering and grading site was then measured with a HunterLab colour meter to provide an instrumental colour measurement at grading. The number on the laminated tag was used for correlation to actual body number, kill floor, grading and subsequent primal cut and consumer packaging and sensory identification codes. Both sides of selected carcasses were identified with large brightly coloured laminated tags carrying an identifying number and secured by 150mm stainless steel skewers. A final 96 sides were selected achieving close to the desired distribution as shown in Table 10 with all but the two meat colour 1C 0 teeth bodies grass-fed.

Table 10. No of carcasses selected within each pH, meat colour and dentition sub-set.

		Meat Colour				
pH	**Dentition**	**1C**	**2**	**3**	**4**	**5**
pH<=5.7	0	4				
	2	2	3	3	2	2
	4		2	4	2	2
	6		1	2	3	2
pH>5.7	0					
	2			1	2	2
	4			2	2	2
	6				1	2

The trial sides were boned as a group with research personnel located at the tenderloin, striploin, and rump tables. Small 50 x 38mm coloured and laminated tags with unique primal numbers linked to the number on the large side tags were placed on each cut as bagged, but not sealed, and the selected primals transferred to tables at the rear of the boning room where each cut was again recorded for AUS-MEAT colour by the same grader who had evaluated the bodies, with a further HunterLab reading also taken.

The primal tags were coloured to indicate specified primal ageing periods of 5, 12 or 40 days. These periods were pre-allocated across each of the 6 cuts within each body to achieve a balanced comparison of primal ageing within each cut. An example for one cell is displayed in Table 11. Thirty-two of each cut were allocated to each ageing period.

Table 11. Ageing allocation example for cuts from 6 bodies within a collection matrix cell

	TENDERLOIN		RUMP		STRIPLOIN	
CUD No	Left	Right	Left	Right	Left	Right
25	40	5	5	12	12	40
26	12	5	40	12	5	40
27	5	12	12	40	40	5
28	40	12	5	40	12	5
29	12	40	40	5	5	12
30	5	40	12	5	40	12

After colour evaluation the cuts were vacuum packed in days aged batches and palletised by ageing period. The pallets were then transferred to the production facility for further processing.

Each primal cut was removed from vacuum packaging, placed on a tray with its ID label, and transferred to a cutting fabrication station where the cut was fully denuded and reduced to a single muscle in the case of the tenderloin (TDR062) and striploin (STR045), with the rump divided into 3 component portions – the rump cap (RMP005) and 2 segments of the rostbiff divided along the seam (RMP131 and RMP231).

A corresponding tray for each primal was prepared with a standard retail 140 x 190mm OWP black foam tray, a 170 x 220mm pre-formed clear plastic (MAP) tray and a third space left for product to be placed in clear VSP (190 x 230mm) trays. The trays were placed in a predetermined order to align with the cut positions. This order was rotated to ensure the packaging methods were applied equally to each position within each cut. The cut, position and packaging combinations were produced through the CUD software together with labelling and allocation of unique EQSRef identification codes. Two sets of the EQSRef codes were individually laminated with one of each to be packed within each retail pack together with soaker pads. The matching labels were placed on paired flavour chemistry samples. Further matching Avery labels were placed across the tray top to provide ID for material retained for proximate analysis.

The packaging and prepared cut trays were then moved to a retail fabrication station where a cutting jig was utilised to cut 25mm slices across the muscle grain as dictated in MSA protocols. Fig. 7 illustrates arrangement of the two rostbiff portions on the cutting jig to cut across the grain.

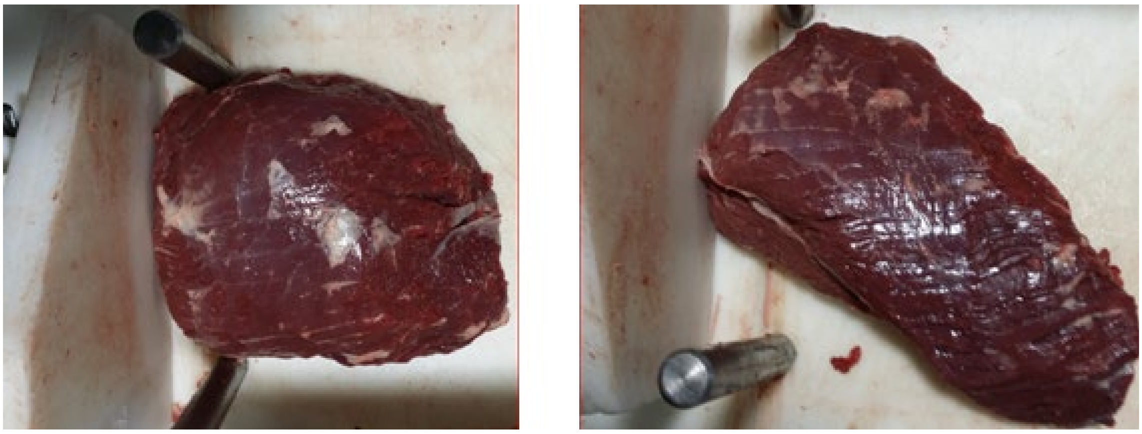


Figure 7. Alignment for slicing on cutting jig for RMP131 (left) and RMP231 (right)

Two to four slices of sufficient size to later allow for division into a total of five 65 x 40 mm consumer samples, were then prepared from each nominated cut position. A packer placed the slices in the associated retail tray, arranged to reflect a retail presentation and placed the laminated EQSRef code within the tray to maintain identification, as shown in the Fig. 8 example.

Figure 8. Control documents and arrangement of packs for retail packaging

A sixth 50 x 50mm portion from each position was prepared for flavour chemistry evaluation and placed in additional packaging specific trays. Five flavour samples, each maintaining individual ID, were placed in each flavour tray to approximate the volume of meat in the retail packs used for consumer observation. Left over scrap material was packed with the objective label, vacuum packed and frozen for storage.

The samples from the rump cap and posterior striploin portion were prepared as 5, 25mm thick, steaks approximately 40 x 65 mm. These were individually wrapped in freezer wrap then placed in a vacuum bag with the Avery label attached for ID and vacuumed. After vacuum packing, they were frozen and retained for use as "Link" samples, served first to all consumers prior to six test samples.

The trays with the remaining 3 retail pack material were then transferred to a colour reading station. After a 20-minute bloom period the same MSA grader utilised in the initial grading and primal packing trial component then viewed each retail tray and assigned an AUS-MEAT meat colour score. Immediately following this HunterLab colour readings (CIE L*a*b* and individual wavelength values) were also taken using D65/10 light source from two steaks within each pack. These observations were then averaged for analysis. In the final 40 days of primal ageing round a prospective new colour measurement device, the NIXPro, was added to the testing routine with duplicate readings taken immediately after and from the identical locations used for the HunterLab.

Immediately following colour analysis, the trays were taken to the relevant retail packing line. The MAP packs were placed directly on a commercial packaging line for sealing while the VSP samples were transferred to the forming section of a commercial VSP (Darfresh™) packaging line. A typical retail butcher wrapping machine (Wedderburn N1793) was used to wrap the overwrap trays with oxygen permeable film.

The OWP trays were placed single depth in suitable containers and despatched via chilled transport to Charles Sturt University and placed in a commercial supermarket retail cabinet on the day of packing. The experimental design specified that the retail display align with supermarket specifications which defined a retail case meeting M0 refrigeration standards of case temperature never exceeding 4˚C and never falling below -1˚C within a room environment where temperature was maintained below 25˚C with a maximum of 50% relative humidity. A suitable case was obtained and installed within an air-conditioned area at Charles Sturt University. The cabinet was fitted with temperature logging equipment throughout the trial period.

The retail MAP and VSP packs were packed in standard cardboard outers and held within plant chillers at 1˚C following standard company procedures. To simulate typical distribution from central fabrication the MAP and VSP product was placed in the cabinet at 48 hours.

Calculations of pack combinations relative to individual shelf areas were made and suitable pack display templates developed to ensure controlled positions for individual packs. The relationship of pack and shelf sizes and required display numbers resulted in stipulated layouts involving a controlled mix of landscape and portrait pack alignment and single (portrait) and double (landscape) row presentation. MAP and VSP packs were specified to be arranged in alternate cabinet sides with the side rotated between display days.

Each display cycle included 96 OWP packs, being 32 of each of the three cuts, and a combined total of 192 MAP (96) and VSP (96) for these products. The protocol specified that the OWP product be displayed immediately after packing, with consumer viewing the day after packaging, and then removed from display to be replaced by the MAP and VSP product to be delivered two days post packing, reflecting normal distribution patterns.

Consequently, the OWP product was viewed alone and acted as a colour control whereas the MAP and VSP were co-located for viewing. In accordance with the protocol all MAP and VSP product was viewed by consumers on three occasions (3, 5 and 7 days post retail packing) after which it was removed from display and returned to the plant for fabrication into consumer sensory samples.

The experimental design further specified that the 8 colour by pH cells within each cut be displayed as a group or set with the order of cabinet layout controlled to ensure that each cell was displayed in a balanced order relative to each other cell. In all there were 4 sets of 8 within each packaging type within each ageing cycle (5, 12 and 40 days in vacuum prior to retail packing). To achieve this an 8 x 8 Latin square design, as designated in Table 12, was employed with the Latin square columns rotated across cuts, packaging, and ageing cycle to achieve a close to balanced meat colour presentation order within every cabinet plan. A further design requirement required dentition within meat colour to be as nearly as possible balanced within each of the 8 tray sets requiring individual allocation of all packs against the designated Latin square rows.

Table 12. Alternative order of retail pack display by AUS-MEAT meat colour and pH[1]

A	1C	2	3-	3+	4-	4+	5-	5+
B	2	3+	1C	4+	3-	5+	4-	5-
C	3-	1C	4-	2	5-	3+	5+	4+
D	3+	4+	2	5+	1C	5-	3-	4-
E	4-	3-	5-	1C	5+	2	4+	3+
F	4+	5+	3+	5-	2	4-	1C	3-
G	5-	4-	5+	3-	4+	1C	3+	2
H	5+	5-	4+	4-	3+	3-	2	1C

[1] + indicates pH over 5.7, - indicates pH of 5.7 or less.

The shelf position of each set of 8 was also rotated between viewings to achieve a mix of front to back (of shelf), left to right and upper to lower shelf to minimise the risk of cabinet position bias in subsequent consumer evaluation. Further nuances were to rotate the positioning of cuts relative to each other and between landscape and portrait presentation. Separation of sets of 8 within the cabinet was reinforced by leaving a small space and by placement of a fresh green capsicum between sets.

Three cabinet plans, one per ageing cycle, were employed to achieve the design parameters for OWP whereas for the MAP and VSP display a different plan was utilised across the 3 display days within each cycle. The designated plans included rotation of product by shelf, by cabinet side and by row on shelf for each of the 4 sets of 8 within each cut by packaging type. Fig. 9 presents an OWP display plan.

				CABINET LAYOUT FOR OVERWRAP TO VIEW ON SUNDAY SEPT 20th													
								TOP SHELF									
					Z4C8	U0Z9	L7E7	J0A6	L4Y5	W8S3	A4Q6	L7F8					
				1AC	T13	T13	T13	T13	T13	T13	T13	T13					
					1	2	3	4	5	6	7	8					
					B2D1	V8K2	E2A9	U9A7	S6U3	S0E7	L9Z9	L1R8					
				1BD	S13	S13	S13	S13	S13	S13	S13	S13					
					1	2	3	4	5	6	7	8					
								2ND SHELF									
					M2Z1	R2L9	X8B8	K3H8	G6E9	V0B6	M6Q4	A8Q9					
				2AC	S14	S14	S14	S14	S14	S14	S14	S14					
					1	2	3	4	5	6	7	8					
					P2P5	C1W8	F7R5	R9R5	D7A1	U5H1	H3G4	R9E9					
				2BD	R13	R13	R13	R13	R13	R13	R13	R13					
					1	2	3	4	5	6	7	8					
								3RD SHELF									
	D7Z5	P2N8	A8T3	X2C1	A0Y5	V0C7	U2L1	Y3E1									
3A	R14	R14	R14	R14	R14	R14	R14	R14	U5D5	W7V8	C3K9	M9B0	B7U4	B9V5	P9U7	F5H0	
	1	2	3	4	5	6	7	8									
									S15	S15	S15	S15	S15	S15	S15	S15	3CD
	X9J7	M4B5	K2L4	S7D0	X1Z3	G3E2	U5V6	D6W0									
3B	T14	T14	T14	T14	T14	T14	T14	T14	1	2	3	4	5	6	7	8	
	1	2	3	4	5	6	7	8									
								4TH SHELF									
					Q6X8	N7M0	C6Z7	M0Z2	Z8C9	V8U2	N5Q5	T6Q5					
				4AC	R15	R15	R15	R15	R15	R15	R15	R15					
					1	2	3	4	5	6	7	8					
					M6U3	R1A7	G0Q3	M8H2	E6B3	D0U1	R2A1	M1H3					
				4BD	T15	T15	T15	T15	T15	T15	T15	T15					
					1	2	3	4	5	6	7	8					
								BOTTOM WELL									
									P9S7	K7Z4	C9M1	M9J1	Z6A8	C7U5	J0M2	T6N0	
	G2U2	G5C0	H9Q6	R0E1	M5B6	U7U0	K4F9	G0N2	R16	R16	R16	R16	R16	R16	R16	R16	5C
									1	2	3	4	5	6	7	8	
5AB	T16	T16	T16	T16	T16	T16	T16	T16	E5Y5	E1S4	E0F8	W3P6	G8E5	R6Q7	R8Y7	L9C1	
	1	2	3	4	5	6	7	8	S16	S16	S16	S16	S16	S16	S16	S16	5D
									1	2	3	4	5	6	7	8	

NOTE: Packs designated in large vertical alignment are in portrait presentation. All others are landscape.

Figure 9. Example cabinet layout for overwrap samples

To facilitate analysis, the position of every pack (by EQSRef) within the cabinet was recorded in combination with the pack order within the specific set of 8. Cabinet positions were designated by code within shelf with 1A the extreme left of the top shelf back row, 1B the extreme left of the front row and 1C and 1D the extreme right, for example. This terminology was extended so that 1AC and 1BD designated central shelf placement in two rows and a 1E central shelf placement where a set was displayed as two rows of 4 and 1CD two rows of 4 at the extreme right. An example plan for the MAP/VSP layouts is shown in Fig. 10.

				CABINET LAYOUT FOR VSP (Shaded) & MAP ON 220915																	
		T4X5	E0E9	Q9J8	F3G5	H9V9	P1P2	S8X0	J4A4			S5X1	L4N4	X9A2	T1E7	B4Q6	B8T6	G8D5	K0C2		
	1A	R17	R17	R17	R17	R17	R17	R17	R17			S21	S21	S21	S21	S21	S21	S21	S21	1C	
		1	2	3	4	5	6	7	8			1	2	3	4	5	6	7	8		
	SHELF 1																				
		Q0S0	S3J7	T8X2	A6M2	B1L1	Q5E8	N2H7	E9C1			T0A6	C5B3	A1Y5	A4A1	A6R7	K6M4	S2V7	L1D8		
	1B	T17	T17	T17	T17	T17	T17	T17	T17			T21	T21	T21	T21	T21	T21	T21	T21	1D	
		1	2	3	4	5	6	7	8			1	2	3	4	5	6	7	8		
		Blue with yellow dots										White Label									
										SECOND SHELF											
	U9K3	Y9E5	M0B6	Y1Q7	X4X6	N7K6	T1N8	X4D6		2E			K3D5	S8X3	N9M0	A0Q3	R2W2	B7R9	Q3Z1	A1E3	
2A	S17	S17	S17	S17	S17	S17	S17	S17	Q6T8	U6H1	U8Y9	L3F8	T24	T24	T24	T24	T24	T24	T24	T24	2C
	1	2	3	4	5	6	7	8	S24	S24	S24	S24	1	2	3	4	5	6	7	8	
									1	2	3	4									
	E1B2	L3H2	W6S6	U0W8	N1A8	N3E8	A1Q8	V1J8	Q1X0	P8L6	Y7E1	V9F5	F2K2	X9P8	K8S8	A5V5	K7T0	U0Q7	B2M6	Q2B4	
2B	R18	R18	R18	R18	R18	R18	R18	R18	S24	S24	S24	S24	R24	R24	R24	R24	R24	R24	R24	R24	2D
	1	2	3	4	5	6	7	8	5	6	7	8	1	2	3	4	5	6	7	8	
	Red Label								Yellow Label				White with red dots								
																		THIRD SHELF			
	D1K1	J1T9	S5T9	C4P6	U7X0	B8B6	J3Q1	W4S6		3E			X2S8	Y9V6	S9C5	Q6G6	N8A4	U4B2	B1M9	E8Z2	
3A	S18	S18	S18	S18	S18	S18	S18	S18	R5B8	D3X7	X3X3	N9J6	R21	R21	R21	R21	R21	R21	R21	R21	3C
	1	2	3	4	5	6	7	8	R19	R19	R19	R19	1	2	3	4	5	6	7	8	
									1	2	3	4									
	G6G2	J9J7	Y7D1	T5K1	Y3X4	C3P7	U0R6	P4F8	H5J1	U3J7	M7F6	J6D1	G4B7	X5L3	E9C9	R2N4	Z1H3	J8F0	A6E3	R7C9	
3B	T18	T18	T18	T18	T18	T18	T18	T18	R19	R19	R19	R19	S22	S22	S22	S22	S22	S22	S22	S22	3D
	1	2	3	4	5	6	7	8	5	6	7	8	1	2	3	4	5	6	7	8	
	Green with orange dots								Green Label				Blue Label								
	FOURTH SHELF										4EC										
	C8A8	M7U0	Y5L0	F4X5	Q1Z7	V4S4	P8S3	D4L3	X1T3	Z1G8	Y1H6	L6K0	Q1Z9	F8N3	Y2X7	S4C5					
4A	T19	T19	T19	T19	T19	T19	T19	T19	S23	S23	S23	S23	S23	S23	S23	S23	Z8C4	A2Y7	L0P4	W1P3	
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	R22	R22	R22	R22	
																	1	2	3	4	4CD
	C4G5	S4R0	E8Q6	R7H5	D8K4	M8E6	V2E1	Q8X9	D9S1	X5S2	J5Q9	K4F7	E0R2	V3X5	Y3F4	N9C4	U1B1	A4W0	R2H2	G8U2	
4B	S19	S19	S19	S19	S19	S19	S19	S19	T22	T22	T22	T22	T22	T22	T22	T22	R22	R22	R22	R22	
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	5	6	7	8	
	Yellow with pink dots								White with blue dots		4ED						White with green dots				
									5AE	BOTTOM WELL											
					W4R8	M8T5	N5V4	M9N3	V7L3	M6C9	N6A8	N0R0	X9V4	V6R5	A0S0	K7T5	G9A8	N5M1	F8D0	B7A3	
	F8N2	F0C2	M9K4	B8J4	S20	S20	S20	S20	S20	S20	S20	S20	T23	T23	T23	T23	T23	T23	T23	T23	5C
	T20	T20	T20	T20	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
5AB	1	2	3	4																	
	W8Q6	C7Q4	V1J7	P4V7	R3P2	N0U3	K3N4	Y8A7	T1E3	W1H6	Q8Q2	S7W4	K6R0	X3V7	E6U5	K2P0	F9T2	N9E3	S5G6	Q0L2	
	T20	T20	T20	T20	R20	R20	R20	R20	R20	R20	R20	R20	R23	R23	R23	R23	R23	R23	R23	R23	5D
	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	Orange Label				Red with yellow dots				5BE				Purple Label								

Figure 10. Example MAP (white) and VSP (shaded) cabinet plan for one viewing

Note: cabinet position designation, set numbers (T=tenderloin, R=rump and S=striploin) and EQSRef order within set representing Latin square column order.

In accordance with the experimental design each pack was assessed by 10 consumers with each consumer required to assess 24 packs being 3 sets of 8 from the 12 on display for OWP or from the 24 for the combined MAP and VSP display. A set comprised 8 retail packages of the same cut sourced from carcasses with 8 combinations of original MSA meat colour (1C, 2, 3, 4 and 5) and pH (above or below 5.7) and dentition from 0 to 6 teeth. This required 40 consumers to view the cabinet when evaluating OWP and 80 for each viewing day of MAP/VSP. Each ageing cycle required 280 consumers to be recruited, a total of 840 for the entire experiment resulting in 20,160 pack observations.

For all OWP observations and for 64 of 80 consumers viewing MAP/VSP the three sets allocated via the design were one of each cut. For 16 of the 80 MAP/VSP consumers only two of three cuts were viewed with the third set a repeat of one cut, the two common cut sets being one in MAP and the other VSP. In all 40 consumers were designated to view 2 MAP and 1 VSP pack and 40 the reverse.

Consumer recruitment was conducted by Charles Sturt University primarily via fundraising with community groups supported by the individual panellists. Where no affiliation was noted a movie pass was offered to the individual. Viewing times were scheduled across the day in 15-minute blocks between 8am and 8pm.

On arrival each consumer was briefed regarding the scoring procedure and given a clipboard with one sheet of demographic questions as shown in Fig. 11 followed by 3 pages, each relating to an assigned set of 8 retail packs identified by EQSRef number and display order within the relevant set of 8. Each set was preceded by an instruction defining the cabinet position such as “Blue Label, top shelf, back row” to assist in accurate location of the first sample.

I.D. ☐☐☐☐

Thank you for your participation today.

Consent for Meat Colour Trial

- There will be no personal monetary gain from this trial however if I am representing an organisation / club / group they will be financially remunerated for my participation.
- My responses in this trial indicate my opinion of meat colour.
- All information collected in this survey is strictly confidential and I will retain anonymity

Name of organisation/club/charity I am representing today

____

I am not representing an organisation, charity or club ☐ *(please tick if applicable)*

I understand the above and agree to participate in this project ☐

(please tick the box if you agree)

Date: D D M M Y Y

1. Gender: *(Use **X** in one box only)*

Male ☐ Female ☐

2. Age Group: *(Use **X** in one box only)*

18-19 ☐ 20-25 ☐ 26-30 ☐ 31-39 ☐ 40-60 ☐ 61-70 ☐

3. From where do you usually purchase your beef? *(Use **X** in all applicable)*

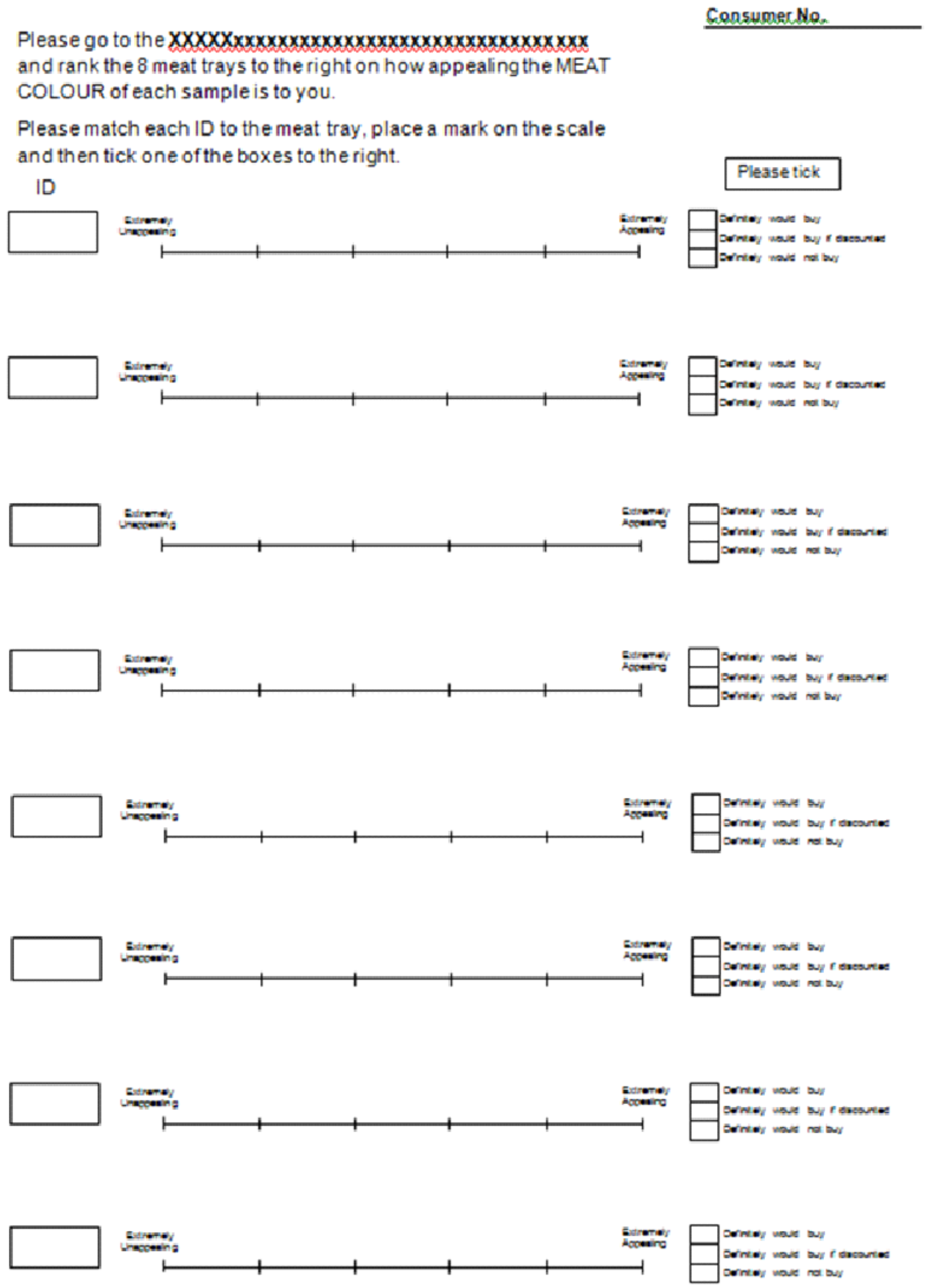
Butcher ☐ Supermarket ☐ Farmers Market ☐ I do not do the beef purchasing ☐

- EACH person will be given a DIFFERENT SET OF SAMPLES to view so please do not compare with other people near you.
- The only correct answer is **your opinion** of meat colour.
- Please score the samples **only** on how appealing **you** think the samples are in **colour**.

  Do not score the samples for your perception of eating quality or for how you think they would cook, taste or eat.
- The friendly staff will explain how to score the samples and assist you if you have any questions.

Figure 11. Consumer demographic questionnaire

Each sample was scored via a 100mm line scale anchored by the words extremely unappealing and extremely appealing. For each sample the consumer was also asked to choose one of three category boxes described as definitely would buy, definitely would buy if discounted and definitely would not buy. An example scoring sheet is shown in Fig. 12. The sample order on each sheet reflected the pack order in the case from left to right with the EQSRef pre-printed in the ID box.



Consumer No.

Please go to the XXXXXxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx and rank the 8 meat trays to the right on how appealing the MEAT COLOUR of each sample is to you.

Please match each ID to the meat tray, place a mark on the scale and then tick one of the boxes to the right.

Please tick

ID

Extremely Unappealing — Extremely Appealing
- Definitely would buy
- Definitely would buy if discounted
- Definitely would not buy

Extremely Unappealing — Extremely Appealing
- Definitely would buy
- Definitely would buy if discounted
- Definitely would not buy

Extremely Unappealing — Extremely Appealing
- Definitely would buy
- Definitely would buy if discounted
- Definitely would not buy

Extremely Unappealing — Extremely Appealing
- Definitely would buy
- Definitely would buy if discounted
- Definitely would not buy

Extremely Unappealing — Extremely Appealing
- Definitely would buy
- Definitely would buy if discounted
- Definitely would not buy

Extremely Unappealing — Extremely Appealing
- Definitely would buy
- Definitely would buy if discounted
- Definitely would not buy

Extremely Unappealing — Extremely Appealing
- Definitely would buy
- Definitely would buy if discounted
- Definitely would not buy

Extremely Unappealing — Extremely Appealing
- Definitely would buy
- Definitely would buy if discounted
- Definitely would not buy

Figure 12. Consumer score sheet for one set of 8 packs (one page of 3)

The consumer was accompanied to the cabinet and assisted in locating the first starting position to ensure the instruction was understood. Fig. 13 displays the cabinet and typical layout.

Figure 13. Retail display for MAP & VSP cycle

Note: label designating first pack in each set of 8.

The line scales for every sample were measured by two independent people, checked again if more than 1mm different, then entered with the demographic data into an electronic file that was emailed to the research manager. These data were then combined with the full data for animal, cut, grading and colour.

After the final viewing period all retail trays were returned to the processing facility where each pack was opened, allowed to bloom for 20 minutes then assessed for colour by the same MSA grader followed by HunterLab readings.

After colour reading, the slices from each pack were fabricated into 5 MSA approximately 65 x 40mm consumer steaks which were individually wrapped in freezer wrap before placing in a vacuum bag, labelled with an Avery self-adhesive label containing Primal, Sequence and EQSRef identification then vacuum packed. The OWP samples were held chilled until the MAP and VSP sample pairs were fabricated and then all frozen 9 days after the initial retail packing date together with the matching flavour samples.

MSA sensory evaluation by untrained consumers was conducted on all retail pack samples to evaluate differences between the three cuts, the alternative ageing periods prior to retail packaging and the three packaging types. This required sensory evaluation of 10,080 grilled beef samples by 1,440 consumers who were recruited as 24 groups of 60 across Melbourne and Wagga locations. Each group were served a controlled combination of cut, packaging, and ageing combinations.

Every consumer was served a first position link sample followed by 6 test samples, one from each of 6 products, presented in a 6 x 6 Latin square order to ensure each product was presented equally in each serving order and before and after each other product. Data was double entered, checked, and then combined with the prior animal, packaging, and colour data.

3.3.4.5. Follow up packaging study.

The packaging study discussed in 3.3.4.4 (P.PIP.0550) produced consistent results of concern to the retail industry, indicating that the predominant MAP packaging format had a detrimental impact on eating quality. Concerns were raised as to whether the use of northern grass fed moderate bos-indicus content cattle, including some with 6 teeth, may have influenced results and differ from more typical supermarket southern specification of young British breeds, including many from feedlot suppliers. Further research questions included whether the observed effect might only be present at the tested 9-day packed period which was close to a typical 10-day use-by date but not present earlier. To address these issues, and also evaluate two alternative MAP gas mixes, a follow up trial was conducted, also at the processing facility.

Given that the first study had found a consistent packaging effect across cuts and primal ageing periods it was agreed that only the M.longissimus dorsi muscle would be utilised from both the cube roll and striploin for the follow-up study with those from both sides collected to allow for a large number of samples within each body. The cut collection was incorporated into the clean label enhancement study reported in 3.3.4.2. This collection utilised a balanced design with grass and grain fed carcasses collected from 5 alternative MQ4 bands aligned with draft PBR. The top category represented high end MSA, the second a step lower but still above the third category based on the lower half of MSA 3*. The lowest two categories were below the MSA 3* cut-off and not utilised in this study.

The striploin and cube roll were collected from both sides of 9 grain and 9 grass-fed carcasses within each of the top three categories for a total of 54 head/108 sides. This provided a balanced representation of grass and grain fed cuts across the MSA spectrum with all from southern British breed cattle, addressing the prior concerns. Nix colour measures and HunterLab measurements were recorded on all selected carcasses in addition to MSA grading measures and slaughter floor data. As described in 3.3.4.4 a laminated tag was packed in the vacuum packaging for every cut with tag colour indicating cuts to be segregated for the packaging study. The collected cuts were aged for 16 days in the chiller prior to further fabrication and retail packaging.

Selected packaging treatments were:

1. Control samples packed in vacuum skin pack (VSP)
2. 80% oxygen:20% carbon dioxide high oxygen MAP (MAP)
3. TriGas, a 40% Nitrogen:30% oxygen:30% carbon dioxide mix (TRI) reported in research literature by the Danish Meat Research Institute
4. An 80% Nitrogen:20% carbon dioxide high nitrogen mix (NIT) reported from trade sources in Europe.

It was agreed that overwrap (OWP) did not require testing due to its' equivalence with VSP in the previous study with VSP and MAP being repeated in the current trial. It was also agreed that all products would be visually rated by untrained consumers in a retail display cabinet 1, 3, 5, 7 and 9 days post retail packing, and sensory tested at each display point to address the question of visual and sensory change over the display period.

The experimental design required the 4 packaging formats to be directly compared across balanced muscle positions, this balance being important due to previously MSA established positional differences along the LD muscle with eating quality reducing from the anterior cube roll portion to the posterior section of the striploin. Three positions, anterior (A), centre (C) and posterior (P) were designated within each muscle for treatment comparisons. The posterior end of the striploin was utilised as "link" to reduce variation between treatments and the *M.spinalis* muscle excluded from the packaging study but packed separately for sensory evaluation. This provided for 5 positions (CUB045 A, C, P and STR A and C) per side available for the packaging treatments.

In addition, 5 aging variations of 1, 3, 5, 7 and 9 days in the retail pack were required within each of the packaging treatments. With the addition of 16 days primal ageing in vacuum this resulted in total sample ageing of 17, 19, 21, 23 and 25 days and a total of 20 treatment variations (4 packaging treatments by 5 ageing periods). By utilising 5 positions within each side the five pack ageing periods of 1, 3, 5, 7 and 9 days were applied to all sides, enabling 5 of the possible 10 ageing comparisons within each carcase. To reduce position by aging interactions it was elected to pair aging treatments within packaging type across the two carcase sides so that, for example as shown in Table 13, the left and right side CUB045 A positions for Body 1 were both MAP packed with the left aged 19 days and the right 17. This arrangement enabled one ageing comparison within each packaging type (8 samples) to be compared in every carcase plus an additional pair from one packaging treatment and two link samples from the STR045 P positions to utilise the 12 available LD positions within each carcase.

Table 13 displays a portion of the MSA CUD file utilised in trial design. The CUB081 samples were designated as GRL, the standard MSA format, and the STR045 P positions all allocated to "LNK". The paired packaging treatment by ageing blocks were rotated along the designated 5 LD positions as illustrated by the 2 (of 9) bodies displayed in 3 (of 6) quality categories.

Table 13. Allocation of packaging and ageing treatments by muscle position

Group	Body	Cut	Tment	Daged	Pos	Side	Group	Body	Cut	Tment	Daged	Pos	Side	Group	Body	Cut	Tment	Daged	Pos	Side
504.1	1	CUB081	GRL	17	C	L	504.2	10	CUB081	GRL	17	C	L	504.3	19	CUB081	GRL	17	C	L
504.1	1	CUB081	GRL	17	C	R	504.2	10	CUB081	GRL	17	C	R	504.3	19	CUB081	GRL	17	C	R
504.1	2	CUB081	GRL	17	C	L	504.2	11	CUB081	GRL	17	C	L	504.3	20	CUB081	GRL	17	C	L
504.1	2	CUB081	GRL	17	C	R	504.2	11	CUB081	GRL	17	C	R	504.3	20	CUB081	GRL	17	C	R
504.1	1	CUB045	MAP	19	A	L	504.2	10	CUB045	MAP	19	A	L	504.3	19	CUB045	TRI	17	A	L
504.1	1	CUB045	VSP	21	C	L	504.2	10	CUB045	TRI	21	C	L	504.3	19	CUB045	NIT	21	C	L
504.1	1	CUB045	TRI	17	P	L	504.2	10	CUB045	TRI	17	P	L	504.3	19	CUB045	VSP	25	P	L
504.1	1	CUB045	MAP	17	A	R	504.2	10	CUB045	MAP	17	A	R	504.3	19	CUB045	TRI	23	A	R
504.1	1	CUB045	VSP	23	C	R	504.2	10	CUB045	TRI	23	C	R	504.3	19	CUB045	NIT	17	C	R
504.1	1	CUB045	TRI	25	P	R	504.2	10	CUB045	TRI	25	P	R	504.3	19	CUB045	VSP	19	P	R
504.1	2	CUB045	VSP	21	A	L	504.2	11	CUB045	VSP	21	A	L	504.3	20	CUB045	MAP	19	A	L
504.1	2	CUB045	VSP	25	C	L	504.2	11	CUB045	VSP	25	C	L	504.3	20	CUB045	MAP	21	C	L
504.1	2	CUB045	MAP	23	P	L	504.2	11	CUB045	MAP	23	P	L	504.3	20	CUB045	TRI	17	P	L
504.1	2	CUB045	VSP	17	A	R	504.2	11	CUB045	VSP	17	A	R	504.3	20	CUB045	MAP	17	A	R
504.1	2	CUB045	VSP	19	C	R	504.2	11	CUB045	VSP	19	C	R	504.3	20	CUB045	MAP	23	C	R
504.1	2	CUB045	MAP	25	P	R	504.2	11	CUB045	MAP	25	P	R	504.3	20	CUB045	TRI	25	P	R
504.1	1	STR045	VSP	23	A	L	504.2	10	STR045	VSP	23	A	L	504.3	19	STR045	NIT	23	A	L
504.1	1	STR045	NIT	25	C	L	504.2	10	STR045	NIT	25	C	L	504.3	19	STR045	MAP	19	C	L
504.1	1	STR045	LNK	17	P	L	504.2	10	STR045	LNK	17	P	L	504.3	19	STR045	LNK	17	P	L
504.1	1	STR045	VSP	19	A	R	504.2	10	STR045	VSP	19	A	R	504.3	19	STR045	NIT	25	A	R
504.1	1	STR045	NIT	21	C	R	504.2	10	STR045	NIT	21	C	R	504.3	19	STR045	MAP	21	C	R
504.1	1	STR045	LNK	17	P	R	504.2	10	STR045	LNK	17	P	R	504.3	19	STR045	LNK	17	P	R
504.1	2	STR045	TRI	19	A	L	504.2	11	STR045	TRI	19	A	L	504.3	20	STR045	VSP	23	A	L
504.1	2	STR045	NIT	17	C	L	504.2	11	STR045	NIT	17	C	L	504.3	20	STR045	NIT	25	C	L
504.1	2	STR045	LNK	17	P	L	504.2	11	STR045	LNK	17	P	L	504.3	20	STR045	LNK	17	P	L
504.1	2	STR045	TRI	21	A	R	504.2	11	STR045	TRI	21	A	R	504.3	20	STR045	VSP	19	A	R
504.1	2	STR045	NIT	23	C	R	504.2	11	STR045	NIT	23	C	R	504.3	20	STR045	NIT	21	C	R
504.1	2	STR045	LNK	17	P	R	504.2	11	STR045	LNK	17	P	R	504.3	20	STR045	LNK	17	P	R

The format of 2 ageing comparisons from each of the 4 pack types per body was firstly assigned across a 5 body layout as displayed in Table 14. As shown in the days aged counts below Table 13, this resulted in a fully balanced muscle position x packaging type by side allocation with a further unallocated pair available.

Table 14. Rotation of ageing by treatment pairs across carcasses

		AGEING		
Body	POS	L	R	PACK
1	CA	3	1	MAP
	CC	5	7	
	CP	1	9	TRI
	SA	7	3	VSP
	SC	9	5	NIT
	SP	LINK	LINK	
2	CA	5	1	VSP
	CC	9	3	
	CP	7	9	MAP
	SA	3	5	TRI
	SC	1	7	NIT
	SP	LINK	LINK	
Days aged counts				
	1	2	2	
	3	2	2	
	5	2	2	
	7	2	2	
	9	2	2	

		AGEING		
Body	POS	L	R	PACK
3	CA	5	7	TRI
	CC	1	9	VSP
	CP	7	3	NIT
	SA	9	5	MAP
	SC	3	1	
	SP	LINK	LINK	
4	CA	9	3	MAP
	CC	7	9	TRI
	CP	3	5	NIT
	SA	1	7	VSP
	SC	5	1	
	SP	LINK	LINK	
Days aged counts				
	1	2	2	
	3	2	2	
	5	2	2	
	7	2	2	
	9	2	2	

		AGEING		
Body	POS	L	R	PACK
5	CA	1	9	NIT
	CC	7	3	MAP
	CP	9	5	
	SA	3	1	TRI
	SC	5	7	VSP
	SP	LINK	LINK	
6	CA	7	9	NIT
	CC	3	5	VSP
	CP	1	7	
	SA	5	1	MAP
	SC	9	3	TRI
	SP	LINK	LINK	
Days aged counts				
	1	2	2	
	3	2	2	
	5	2	2	
	7	2	2	
	9	2	2	

		AGEING		
Body	POS	L	R	PACK
7	CA	7	3	
	CC	9	5	TRI
	CP	3	1	VSP
	SA	5	7	NIT
	SC	1	9	MAP
	SP	LINK	LINK	
8	CA	3	5	
	CC	1	7	MAP
	CP	5	1	TRI
	SA	9	3	NIT
	SC	7	9	VSP
	SP	LINK	LINK	
Days aged counts				
	1	2	2	
	3	2	2	
	5	2	2	
	7	2	2	
	9	2	2	

		AGEING		
Body	POS	L	R	PACK
9	CA	9	5	VSP
	CC	3	1	NIT
	CP	5	7	MAP
	SA	1	9	
	SC	7	3	TRI
	SP	LINK	LINK	
10	CA	1	7	TRI
	CC	5	1	NIT
	CP	9	3	VSP
	SA	7	9	
	SC	3	5	MAP
	SP	LINK	LINK	
Days aged counts				
	1	2	2	
	3	2	2	
	5	2	2	
	7	2	2	
	9	2	2	

The unallocated positions in Table 14, represented in Table 13 by dark red cell borders, were then filled by rotating the packaging treatments with ageing pairs against the empty cells in Table 14. This resulted in each ageing comparison being represented once across each pair of bodies as read vertically. When repeated on a second body, the lower half of Table 5, each packaging treatment was repeated twice and each ageing comparison (1:3, 1:5, 1:7, 1:9, 2:3, 2:5, 2:7, 2:9, 3:5, 3:7, 3:9, 5:7, 5:9, 7:9) included once in each position as read to the right.

When extended this produced 540 retail tray samples (10 samples x 54 bodies of 3 quality categories) subdivided into 108 trays for each day's ageing, 27 per packaging treatment. This design was consequently implemented utilising the MSA CUD software and supplementary processes.

The processing facility staff were allocated to the trial work on a Saturday to enable the research design and ancillary requirements for access to work areas and packaging lines to be met. Staff firstly removed each primal from vacuum packaging, placing the laminated primal label on a tray. The cut was then denuded, and the spinalis (CUB081) separated from the CUB045 muscle for the cube roll cuts, with the denuded muscle(s) placed with the ID label and the tray moved to a cutting station where a cutting jig was utilised to produce 25mm slices from each striploin and cube roll eye. The slices were placed in order along the tray to retain position. The CUB081 was rolled and then sliced to 25mm sensory samples. These CUB081 samples were also placed on the tray adjacent to the CUB045 slices.

The tray was then transferred to a packing station where it was matched to a second tray carrying the same Primal ID. This tray had been assembled by a further research team member who placed the 3 packaging trays in cut position order on the tray over coloured sheets that designated MAP, TRI, NIT or VSP treatments for the STR045 and CUB045 muscle positions. Laminated EQSRef ID labels were placed in each tray and a coloured dot sticker designating retail display days was placed on the side. Packaging trays used were standard retail 170 x 220mm pre-formed clear plastic (MAP) trays with soaker pad for the MAP, TRI and NIT and 190 x 230mm clear VSP trays which were formed within the packaging equipment.

At the packing station slices were packed in each tray proceeding in the nominated position order and the laminated EQSRef ID label placed within the tray. An overview of the slicing and packing activity is shown in Fig. 14.

Figure 14. Overview of slicing and packing station

The LINK product and spinalis (CUB081) were VSP packed and sent directly to the VSP packing line for packing. As these were not utilised in the retail display, they were placed in chilled storage for ageing prior to freezing until needed for consumer sensory testing.

The tray with the filled retail packs was then transferred to a colour recording station and all samples bloomed for 20 minutes. The same MSA grader utilised in the initial grading and primal packing trial component then viewed each retail tray and assigned an AUS-MEAT meat colour score.

Recordings for each tray were also made with HunterLab and NIX instruments. The trays were then sorted into packaging type and processed through the relevant packaging line. After packaging they were assembled by display period, indicated by coloured dot, and packed in cardboard outers.

A further set of trays were packed from a common batch of ground beef and again packed through each packaging system with the same mix of retail ageing periods, again indicated by colour coded stickers.

All product was transferred to CSU and stored in the kitchen area chillers after completion of fabrication.

Two commercial chilled retail display cabinets were utilised at Charles Sturt University, one for steak and the other for mince evaluation. The steak cabinet utilised a three-deck display plus well and was of a type widely used in Australian supermarkets. The number of packs able to be displayed was constrained by the shelf dimensions with 144 packs the maximum. As there were a total of 540 packs, 108 per display day allocation, it was not possible to always have all packs on display. To enable a consistent full cabinet for evaluation the design shown in Table 15 was adopted.

This dictated that the 108 packs designated for a particular day were interspersed with a constant 36, 9 per packaging type, from the 9-day samples. On day 9 only 108, the entire 9-day cohort were displayed.

The mince cabinet dimensions were such that 44 trays could be displayed on day one with 8 being removed, 2 of each packaging treatment after each viewing day leaving a residual 12 on day 9.

Table 15. Number of steak packs displayed by treatment and days post retail packing.

	DAYS IN RETAIL PACKAGING					
TREATMENT	**1**	**3**	**5**	**7**	**9**	**Total**
MAP-1	27					**27**
MAP-3		27				**27**
MAP-5			27			**27**
MAP-7				27		**27**
MAP-9	9	9	9	9	27	**27***
TRI-1	27					**27**
TRI-3		27				**27**
TRI-5			27			**27**
TRI-7				27		**27**
TRI-9	9	9	9	9	27	**27***
NIT-1	27					**27**
NIT-3		27				**27**
NIT-5			27			**27**
NIT-7				27		**27**
NIT-9	9	9	9	9	27	**27***
VSP-1	27					**27**
VSP-3		27				**27**
VSP-5			27			**27**
VSP-7				27		**27**
VSP-9	9	9	9	9	27	**27***
TOTAL	**144**	**144**	**144**	**144**	**108**	**540***
Consumers	90	90	90	90	68	**428**

* Adjusted to actual total packs

To balance out potential case position and adjacent packaging type effects each packaging treatment was allocated within an 8 x 8 Latin square design with two of each packaging type, one grass fed, and one grain fed, within each "set" of 8 and the relative order of each type rotated according to rows within the Latin square. The three quality levels of product within grass and grain were also evenly distributed across the Latin Square rows and order. The Latin square rows or "sets" were further rotated within shelf (Top to well) and shelf position (front, back, right, and left and centre for the well only).

An example of a "set", representing one of 8 Latin Square rows used to determine pack order on the cabinet shelf is displayed in Table 16.

Table 16. Example of allocation pack quality, display order and cabinet position for an example set.

GROUP	CUD No	BODY No	Primal	EQS	Set No	Order	Cab Pos	Description	Cut	Cook	Age
Premium GRAIN	9	824	55128	P1N6	18	1	3D	BLUE. THIRD shelf. FRONT row. RIGHT side.	CUB045	VSP	25
Classic GRAIN	19	559	55171	R9Q9	18	2	3D	BLUE. THIRD shelf. FRONT row. RIGHT side.	STR045	NIT	25
Premium grass	18	149	55167	A5X0	18	3	3D	BLUE. THIRD shelf. FRONT row. RIGHT side.	STR045	VSP	25
Premium GRAIN	9	824	55131	R9F6	18	4	3D	BLUE. THIRD shelf. FRONT row. RIGHT side.	STR045	TRI	25
Classic grass	30	208	55214	R3Z0	18	5	3D	BLUE. THIRD shelf. FRONT row. RIGHT side.	CUB045	MAP	25
Classic GRAIN	19	559	55168	F8P8	18	6	3D	BLUE. THIRD shelf. FRONT row. RIGHT side.	CUB045	VSP	25
Premium grass	18	149	55164	W2J9	18	7	3D	BLUE. THIRD shelf. FRONT row. RIGHT side.	CUB045	VSP	25
Classic grass	30	208	55212	R6Z2	18	8	3D	BLUE. THIRD shelf. FRONT row. RIGHT side.	CUB045	MAP	25

Referring to Table 16 the GROUP indicates the product eating quality category and whether from grass or grain fed carcasses. The source cut, cooking method and days aged from slaughter (with the first 16 days as a vacuum packed primal) to the date of display are shown to the right. The unique pack ID for each pack is the EQSRef with the order of display and cabinet position 3D assigning the 8 packs to the front of the third cabinet shelf, right hand side in the designated 1 to 8 order (See Table 12 for shelf designation coding).

The description “BLUE, THIRD shelf, FRONT row, RIGHT side” and the EQSRef was reproduced utilising an R software routine on the 10 related consumer scoring forms to guide the consumers to the 8 trays for assessment with “BLUE” indicating a blue label attached to the starting shelf position (See cabinet in Fig. 16).

The 36 packs allocated to display across the entire period were maintained in a fixed cabinet position as a reference point across each display period. All packs not on display were held in a CSU chiller at approximately 3˚C.

CABINET LAYOUT FOR CSU COLOUR TRIAL - DAY 1 - MONDAY Nov 6th, 2017

	TOP SHELF																
	F9D9	M4T2	F1H4	Z8K9	W6X0	H9K2	M6V9	Y7S3	L4Q8	W8A8	Y5B2	C8V2	Y6W1	Y0R9	N0J3	X6V0	
1A	Set10	Set10	Set 10	Set10	Set10	Set10	Set10	Set 10	Set3	Set3	Set3	Set 3	Set 3	Set3	Set3	Set3	1C
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	S0F8	S2A1	N5Z8	Q3S8	N0D7	C4A3	S6G0	Z5H9	M8Q8	Z1U2	X3B3	S3T2	F9Y7	E6D1	Z6K4	N7B4	
1B	Set15	Set15	Set 15	Set15	Set15	Set15	Set15	Set 15	Set8	Set8	Set8	Set 8	Set 8	Set8	Set8	Set8	1D
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	WHITE with BLUE dots								GREEN								
	SECOND SHELF																
	F5D2	W4T2	P1S7	G9L2	R7D5	B6K6	J0X5	S9A8	N7J8	Z3Z3	F4Z6	P2X8	D1V8	W5B7	M3F6	P8B3	
2A	Set1	Set 1	Set 1	Set1	Set1	Set1	Set 1	Set 1	Set17	Set17	Set17	Set17	Set 17	Set17	Set17	Set17	2C
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	L0T0	D1F5	Q0F3	R4F1	F3E6	S9J1	H9D3	Z3Z6	D1S1	Q9N1	N3J5	V5N2	T2P1	E0R5	T3V0	G5V6	
2B	Set6	Set 6	Set 6	Set6	Set6	Set6	Set 6	Set 6	Set12	Set12	Set12	Set12	Set 12	Set12	Set12	Set12	2D
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	RED								WHITE								
	THIRD SHELF																
	A5A2	C9W6	M2P3	A5T2	Y5V1	M6M7	L1C6	D2G3	E1T6	J2P2	U5P6	S9G6	T9G9	Y2A7	U3D1	Q0Q7	
3A	Set 14	Set14	Set 14	Set14	Set14	Set14	Set14	Set 14	Set9	Set9	Set9	Set 9	Set 9	Set9	Set9	Set9	3C
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	M7M6	J0R5	M9S6	D0F0	T9R7	R5E5	V1B0	C5G0	P1N6	R9Q9	A5X0	R9F6	R3Z0	F8P8	W2J9	R6Z2	
3B	Set7	Set 7	Set 7	Set7	Set7	Set7	Set 7	Set 7	Set18	Set18	Set18	Set18	Set 18	Set18	Set18	Set18	3D
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	GREEN with ORANGE dots								BLUE								
	BOTTOM SHELF																
	V6C2	P0T6	F9N8	R5G7	F9J9	Y0B0	S6Y4	L8W3	E6P0	C9B3	R9D2	Q8N7	C7K9	K5Y7	D0D5	R9T5	
4A	Set11	11	11	11	11	11	11	11	Set4	Set4	Set4	Set 4	Set 4	Set4	Set4	Set4	4D
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	V3F5	D6S7	E7Y8	L5T4	L2C3	E8P6	E0B6	R1R9	A0G3	F4U5	P2M7	Y6D1	V7Y7	C8S9	U3Q8	W6S2	
4B	Set16	Set16	Set 16	Set16	Set16	Set16	Set16	Set 16	Set13	Set13	Set13	Set13	Set 13	Set13	Set13	Set13	4E
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	W9R4	M7U1	U9T2	R7X5	Q4H9	X2U9	Z6D3	D0U4	W1F7	T2D5	R7A0	G6Q6	S7A2	Y4P1	U0D4	F7C1	
4C	Set2	Set 2	Set 2	Set2	Set2	Set2	Set 2	Set 2	Set5	Set5	Set5	Set 5	Set 5	Set5	Set5	Set5	4F
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
	YELLOW								WHITE with PINK dots								

MINCE CABINET

	TOP SHELF					
	V0E0	E5U2	S4J2	V3H1	G4M0	
1A	Set 20	Set 20	Set 20	Set 20	Set19	5E
	1	2	3	4	1	
	A9A7	U0R8	C4E1	N8F1	T0J8	
1B	Set 22	Set 22	Set 22	Set 22	Set19	5E
	1	2	3	4	2	
	RED				WHITE Label	
	SECOND SHELF					
	K4P3	X2A3	R4B0	N2J8	G4M7	
2A	Set 22	Set 22	Set 22	Set 22	Set19	5E
	5	6	7	8	3	
	W2T3	K1G0	P7J8	Z7A2	P7S6	
2B	Set 23	Set 23	Set 23	Set 23	Set19	5E
	1	2	3	4	4	
	BLUE				WHITE Label	
	THIRD SHELF					
	V0R4	R9F7	D3M8	Q9H9	D9R6	
3A	Set 21	Set 21	Set 21	Set 21	Set19	5E
	1	2	3	4	5	
	W2V3	S3Y0	D9W4	T1U9	V0C4	
3B	Set 23	Set 23	Set 23	Set 23	Set19	5E
	5	6	7	8	6	
	GREEN				WHITE Label	
	BOTTOM SHELF					
	K5W2	K3E9	T1L1	M7G3		
4A	Set 20	Set 20	Set 20	Set 20		5E
	5	6	7	8		
	R2P9	Z2C9	N8U9	N7P8	B4V4	
4B	Set 21	Set 21	Set 21	Set 21	Set 19	5E
	5	6	7	8	7	
	X0J4	J0E4	A6A9	L8H8	J5H0	
4C	24	24	24	24	Set 19	5E
	1	2	3	4	8	
	YELLOW				WHITE Label	

Figure 15. Cabinet Plan for Day 1 retail viewing display

Individual case layouts were produced for each viewing day (1, 3, 5, 7 and 9 days from packing) with the 108 of the applicable day packs and 33% (36 packs) of the 9-day treatment displayed for consumer evaluation. A typical cabinet plan allocating each EQSRef to a specific position within its' set and shelf position is shown in Fig. 15 with the constant 9-day samples shaded blue.

Each consumer visually evaluated 3 sets of 8 packs. One set of 8 was mince for many consumers with the mince packs displayed in a second cabinet. Ten consumers evaluated each pack utilising the same scoring system as used in the original packaging study. The cabinet and associated layout is shown in Fig. 16.

Figure 16. Retail display cabinet.

Note: mix of packaging treatments and coloured locator flags

After viewing, the 108 packs for that day were removed for colour measurement by HunterLab and visual AUS-MEAT assessment by an MSA grader and converted to MSA grill consumer sensory samples which were then frozen to enable consumer testing at each display period. The 36 nine-day packs remained in the cabinet throughout the display period with the additional 9 day packs added to display all 108 on the last viewing day.

MSA sensory evaluation by untrained consumers was conducted on all 540 retail pack grill samples to evaluate differences between the 4 packaging treatments and 5 ageing periods. The product was tested within 19 groups of 60 Melbourne consumers (each group of 60 comprising a pick) with linkage to other trials through some picks having product from two or more experiments included. Two further picks were conducted to evaluate the mince packaging treatments. All consumer testing was conducted in the greater Melbourne area by Tastepoint Pty Ltd.

All colour scoring and sensory data was double entered and checked for variance prior to forwarding for addition to the AUSBlue MSA grading, packaging and ageing data. Independent statistical analysis was conducted by Dr Ray Watson, Dr Garth Tarr and Professor John Thompson and presented to the MSA Pathways Committee for review.

3.3.4.6. Long term ageing in Thermoform packaging.

Direct packing of retail ready product using Thermoform packaging post boning was identified by as providing a potentially attractive alternative to vacuum packing in shrink bags. While Thermoform was a form of vacuum packaging the pack evacuation was less than observed in shrink bags with visible space, particularly in pack corners.

An important knowledge gap related to the comparative shelf life of the two systems including potential flavour development over extended ageing periods. Some incentive for the study reflected consumer testing of USA sourced product at TTU. In that study of 120 striploins ageing had produced a noticeable decrease in consumer satisfaction from 21 days ageing to 84 days driven by flavour change. In contrast were able to claim a 120 day shelf life on vacuum packed primals, reflecting excellent in-plant hygiene and temperature control. The agreed research study was commissioned to evaluate Thermoform shelf life impact as measured by MSA untrained consumer sensory protocols focussing on cuts supplied to the Chinese market.

It was agreed that cut collections would be made from typical China eligible grass fed bullocks and from China eligible grain fed cattle. The trial design incorporated key cuts of interest and ageing periods from 21 to 140 days in 7 day increments in order to establish ageing curves for individual cuts. Only Thermoform product was packed on the assumption that the performance of long aged vacuum packed product in shrink bags was well established and, assuming oxygen evacuation was unlikely to be better in Thermoform, ageing data would provide a conservative basis for shrink bag performance.

The nominated “China” primal cuts are displayed in Table 17 together with the planned number of consumer samples planned from each (both sides) and selected cooking method.

Table 17. Selected primal cuts, no of consumer samples and cooking method.

Primal	Samples /Body	Cooking Method
Chuck	6	Grill
Cube roll	6	Grill
Striploin	6	Grill
Point end deckle off Brisket	6	Stirfry
Rib fingers	1	Stirfry
Heel muscle	4	Stirfry
Shin special trim*	10	Stirfry

* Includes muscles from FQS and HQS

The shin specification called for individual testing of major muscles within both the fore shin and hindquarter shank, resulting in 10 individual samples from each body whereas the rib fingers (intercostals) assumed only a single sample could be obtained. Grill and stir-fry cooking methods were allocated to individual muscles in accordance with their size and form or expected cooked performance. Cuts were subsequently collected at both plants with the 18 bodies at each selected from China eligible carcasses and successfully meeting MSA grade requirements. Grading data was recorded for all trial bodies and laminated unique ID tickets pinned to each cut with 150mm stainless steel pins. An example set of tickets showing a reference carcase side ID, unique Primal reference number and cut description is shown in Fig. 17.

3 L	3 L	3 L	3 L
59865	59864	59863	59862
Chuck Roll	Heel	Striploin	Cube Roll
3 L	3 L	3 L	3 L
59869	59868	59867	59866
Rib Fingers	HQ Shin	FQ Shin	PEDO

Figure 17. Example ID tickets for one carcase side

All cuts were collected off the boning chain with the ID label packed in a vacuum bag at the slicing station for each primal, and the pins retrieved. The bags were not sealed and assembled in dollies for transfer to a work area where they could be prepared for final Thermoform packing and labelling within the boning room.

MSA and Birkenwood design software was utilised to assign ageing periods to individual cut positions and achieve balanced ageing x position rotations within each muscle type. Where 6 samples were available for the two cuts off one body one sample was allocated within each of 6 ageing period ranges being:

- One sample from either 21, 28 or 35 days ageing
- One sample from either 42, 49 or 56 days ageing
- One sample from either 63, 70 or 77 days ageing

- One sample from either 84, 91 or 98 days ageing
- One sample from either 105, 112 or 119 days ageing
- One sample from either 126, 133 or 140 days ageing

This ensured every cut was tested across an extensive range of ageing with the combinations stepped to achieve balanced numbers at each 7 day interval across the full collection. Table 18 displays allocations for chucks.

Table 18. Example of ageing allocation across chuck primal portions

	DAYS AGED																		
CHK	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**70**	**77**	**84**	**91**	**98**	**105**	**112**	**119**	**126**	**133**	**140**	**TOTAL**
Body	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**5**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**107**
2			1			1			1			1			1			1	6
4	1			1			1			1			1			1			6
7		1			1			1			1			1			1		6
8			1			1			1			1			1			1	6
9	1			1			1			1			1			1			6
10		1			1			1			1			1			1		6
12			1			1			1			1			1			1	6
14	1			1			1			1			1			1			6
16		1			1			1			1			1			1		6
17			1			1			1			1			1			1	6
20	1			1			1			1			1			1			6
22		1			1			1			1			1			1		6
24			1			1			1			1			1			1	6
26	1			1			1						1			1			5
28		1			1			1			1			1			1		6
31			1			1			1			1			1			1	6
33	1			1			1			1			1			1			6
37		1			1			1			1			1			1		6

Where less than 6 samples were possible the rotations were extended across additional bodies as required. Where sufficient meat was available beyond 6 samples an additional 14 day sample was fabricated.

To provide instruction for sample fabrication individual lines from the CutUpFile produced by the MSA CUD software were printed and laminated to detail each sample required. These strips were placed adjacent to the cut when it was removed from the bag for fabrication. After required trimming the cut was divided into the designated portions, retaining positional order. The strips were checked to confirm correct allocation to the Primal number collection ticket then placed on top of the assigned portions. The portions and ID strip were then transferred to the Thermoform machine and placed within the formed pocket over a soaker pad and with the label on top and clearly visible for subsequent ID after lidding. An example set of strip labels for one primal is shown in the Fig. 18 example.

BODY	Primal	Cut	Pos	Seq	EQS	Cook	Age	Obj	FREEZE
1	**59830**	CUB045	A	AUS114505	A6H3	GRL	21	y	**Jan 2nd**
1	**59830**	CUB045	C	AUS114506	T5T0	GRL	42	y	**Jan 23rd**
1	**59830**	CUB045	P	AUS114507	L2M2	GRL	63	y	**Feb 13th**

Figure 18. Example of laminated control labels for one cut

After packaging was completed all Thermoform packs were transported to the CSU Wagga Meat Laboratory for ageing and MSA consumer sample fabrication.

On arrival at CSU they were checked for leakers and sorted into freeze down date groups within cooking method. On each freeze down date stir-fry samples were frozen whereas grill samples were removed from the packs for fabrication. Control instructions and associated labelling files were produced by the CUD software system ensuring linkage to the source animal, carcase, grading and primal cut position data. A cutting jig set to 25mm was used to produce slices across the grain direction with the slices then fabricated into 5 steak portions, approximately 40 x 65mm which were individually wrapped and vacuum packed. A further small steak portion was separately packed for flavour chemistry analysis. All packs were uniquely labelled with Avery self-adhesive labels containing the Primal number, sequence number and sample EQSRef.

At the completion of the 140 day ageing period consumer picks were designed to test all sensory samples. Following MSA protocol each pick, supplying 7 samples to each of 60 consumers, required 42 sensory samples. Six samples were allocated as first served link product and sourced from other meat. The remaining 36 were allocated within 6 test products reflecting groupings based on muscle and ageing period to provide a range of sensory response with each consumer served one of each product in a 6x6 Latin square controlled order. Each sample was evaluated by 10 consumers.

For stir-fry picks the chuck and brisket samples had been prepared as standard MSA stir-fry protocol 20 x 75 x 150mm blocks during plant fabrication. These blocks were tempered in a microwave then sliced on an electric slicer parallel to the grain direction following the protocol. The shin and intercostal muscles were of unsuitable shape and size for the standard procedure and were instead partially thawed then hand cut by skilled butchers. For each sample 22 approximately 10 x 10 x 75mm strips were produced and packed into labelled containers for cooking prior to the consumer event within 48 hours of preparation. Cooking was conducted to MSA protocol with all steps controlled by count up timer in relation to a timing chart dictating time for samples being added to the wok, addition of glaze, heat control and transfer from the wok.

The grill samples were “posted” following MSA protocol prior to cooking at the sensory venues with typical picks including samples from other MSA projects to provide statistical linkage. Cooking was conducted on 3 phase Silex S-Tronic 165 grills.

Sensory testing was conducted in multiple locations by Tastepoint, UNE and CSU sensory teams in country regions and Sydney from UNE and CSU and in Melbourne and Brisbane by Tastepoint. All sensory data was double entered, checked, and merged into AUSBlue by software to connect sensory outcomes to all animal, grading and fabrication data. Flavour chemistry samples were stored in -80˚C freezers.

3.3.4.7. Briskets and Ribs

Brisket and rib cuts were identified as having potential for value adding based on observation of their popularity in USA where "low and slow" cooking in a smoker is a longstanding cultural tradition. The recent introduction of Australian competitive smoked brisket activities provided early evidence that the product might also be appreciated by Australian consumers. It was believed that upgrading of these cuts, which have substantial weight, from disposal as trim through an alternative cooking method that increased consumer satisfaction could add substantial company revenue through raw material or fully cooked offers.

The considerable experience of the Texas Tech Meat Science group was heavily utilised in developing a research protocol to address a number of pertinent questions including:

1. Potential interaction of raw material quality based on PBR.
2. Potential influence of grass and grain fed.
3. Possible muscle or muscle position differences.
4. Influence of serving form – sliced, chopped, or pulled.
5. Potential differences between serving hot directly from the smoker relative to packing for chilled retail display then reheating.
6. Comparison of USA and Australian consumer sensory response.
7. All aspects to be measured by MSA compliant consumer testing.
8. Cooked yield measurement.

It was agreed that the initial detailed study be conducted at TTU to leverage their existing equipment and knowledge base then replicated with paired Australian product at UNE in Australia with this work funded through L.EQT.1814. It was further agreed that product from several USDA grades be included in the TTU studies to provide linkage to Australian grass and grain fed.

The Australian brisket and rib raw material collection was integrated into a single large and complex cut collection to fill required product categories. The collection included cuts utilised in the enhancement study reported in 3.3.4.2 and the packaging study reported in 3.3.4.4. In brief the collection protocol collected cuts, including point and navel end briskets and short ribs, from subsets of 9 grass and grain fed cattle across 5 eating quality bands defined by PBR specifications. Categories included 3 levels of MSA eligible carcasses, a lower "Value Add" category and manufacturing cow. Nine grass and 9 grain fed carcasses were selected within all categories along with manufacturing cow from 18 grass fed carcasses.

Cuts were collected from both carcase sides generating 180 of each. Coloured laminated unique Primal ID tags were packed with each cut, the colour designating freezing and USA or UNE destinations. The brisket and rib primal from both sides of 6 bodies within each subset of 9, and 12 of the 18 manufacturing cows, was designated for TTU in addition to those from one side of the remaining 3 from each subset of 9 and 6 cows. Cuts from the alternate side of the subsets of 3 head within each category and 6 cows were allocated to UNE to provide paired samples. All brisket and rib product were frozen immediately after boning at 3 days post-mortem in line with plant practice and transported frozen.

TTU personnel collected point end brisket and short ribs from 16 head from each of USDA Prime, mid Choice and Select grade specifications at a Nebraska packing house.

A series of trials were conducted by Birkenwood, UNE and TTU personnel in the TTU Meat Laboratory to develop cooking and serving protocols. A new MSA cooking and serving protocol, designated TBQ (Texas BBQ) was developed which involved cooking full briskets after a light salt and pepper rub. To ensure identical cooking at TTU and UNE Green Mountain Jim Bowie Model Wood Pellet smokers were purchased for use at both locations. A standard USA sourced wood pellet, available in Australia, was also specified.

Raw point or navel end briskets were trimmed and lightly seasoned (salt & pepper) 14 hours prior to placing fat side down in the smoker after reaching the temperature set point of 250˚F / 121˚C. Each brisket was weighed and identified with an ovenproof tag prior to cooking. Internal brisket temperature was monitored regularly by placing the smoker probe in the smallest brisket within the smoker. When the internal temperature reached 150˚F / 66˚C the brisket was removed and wrapped in heavy duty aluminium foil then returned to the smoker in the same orientation with time recorded. When the internal temperature reached 200˚F / 93˚C the brisket was removed, left in the foil wrapping and placed in an insulated holding box with time recorded. Briskets were rested for a minimum of 30 minutes. Ninety minutes prior to the planned consumer taste panel start time, the brisket was removed from storage, unwrapped, weighed, and processed.

After reaching an agreed cooking protocol a control Cook Record sheet format was developed to record time, temperature, and weights and to specify the serving form from individual muscle portions. An example Cook Record is displayed in Table 19. Each research cooking event, and associated Cook Record, utilised the 42 individual samples required for a consumer “pick”, each requiring 60 consumers to be served in a single sitting.

Table 19. Example of smoked brisket Cook Record

Night	1520		COOK RECORD				Date RHT			Date HOT			
Carcase	Primal No	Cold Wt	Time In	Time Wrap	Time Out	Cut Hot Wt	Muscle	Muscle Wt	Position	SERVE	EQSref	Check	COOK
808	54445						BRI056		N	C	Q6U6		RHT
808	54445		Temp	Temp	Temp		BRI056		P	P	A3V9		RHT
808	54445						BRI057		V	P	J7Y9		RHT
808	54445						BRI057		D	S	Q8X7		RHT
808	54447						BRI056		N	C	B9D1		HOT
808	54447		Temp	Temp	Temp		BRI056		P	P	K4N6		HOT
808	54447						BRI057		V	P	J3X4		HOT
808	54447						BRI057		D	S	R9G2		HOT
619	54561						BRI056		N	P	G5Z8		HOT
619	54561		Temp	Temp	Temp		BRI056		P	S	X5R8		HOT
619	54561						BRI057		D	C	Y0S6		HOT
619	54561						BRI057		V	S	V6Z3		HOT
619	54563						BRI056		N	P	Z0D0		RHT
619	54563		Temp	Temp	Temp		BRI056		P	S	X6S3		RHT
619	54563						BRI057		D	C	T8P1		RHT
619	54563						BRI057		V	S	R9Q1		RHT
722	54707	Temp					BRI056		C	C	L0G7		HOT
722	54707						BRI057		C	P	U9J2		HOT
722	54709	Temp					BRI056		C	C	G0A7		RHT
722	54709						BRI057		C	P	L9N3		RHT
18	56297						BRI056		P	C	R1L3		HOT
18	56297		Temp	Temp	Temp		BRI056		N	S	G0M6		HOT
18	56297						BRI057		V	C	P3U7		HOT
18	56297						BRI057		D	P	M9U3		HOT
18	56300						BRI056		P	C	R0N7		RHT
18	56300		Temp	Temp	Temp		BRI056		N	S	W4W1		RHT
18	56300						BRI057		V	C	R8K8		RHT
18	56300						BRI057		D	P	A2R2		RHT
36	56405						BRI056		N	P	H5A7		RHT
36	56405		Temp	Temp	Temp		BRI056		P	S	U7U5		RHT
36	56405						BRI057		D	C	D4B0		RHT
36	56405						BRI057		V	S	W5Y9		RHT
36	56408						BRI056		N	P	F3G0		HOT
36	56408		Temp	Temp	Temp		BRI056		P	S	G0B8		HOT
36	56408						BRI057		D	C	L0V5		HOT
36	56408						BRI057		V	S	Y4S1		HOT
4	57243						BRI056		P	S-Link	J9V3		HOT-L
4	57243		Temp	Temp	Temp		BRI056		N	S-Link	L1Z0		HOT-L
4	57243						BRI057		C	S-Link	K7G6		HOT-L
4	57244						BRI056		P	S-Link	Y8E4		HOT-L
4	57244		Temp	Temp	Temp		BRI056		N	S-Link	A2H6		HOT-L
4	57244						BRI057		C	S-Link	G1C2		HOT-L

Referring to the Cook Record in Table 19 identification of the source body is followed by the laminated Primal ID packed with each cut at collection. A cold weight and progressive time and temperature records for foil wrapping and final removal from the smoker is shown in subsequent columns. A hot weight of the full primal after removal was recorded to enable cook loss to be calculated and then the weight of the individual muscle portions recorded. The Position and Serve columns provided instruction for consumer sample fabrication, sliced (S), chopped (C) or pulled (P) from each muscle position and the final individual sample unique EQSRef code. Laminated tags carrying the EQSRef code were placed with each sample to retain ID with these allocated to the specific animal, side, primal, muscle position linkage within AUSBlue to ensure all data was accumulated for analysis.

In the far right column an allocation was made to HOT or RHT. Samples designated as RHT (reheat) were cooked 7 days prior to their HOT pairs, with Body 808 as an example having the brisket from one side designated RHT and that from the other side HOT.

Cooking and sample preparation procedures were identical for both RHT and HOT with the only difference relating to the RHT samples being vacuum packed, chilled, and stored for 7 days replicating a retail cook chill process. The RHT samples were removed from chilled storage no less than 5 hours prior to serving and rested at room temperature for an hour before being placed in a Sous-vide water bath set at 50°C for a minimum of 3 hours. Each bag was then emptied into a 1/9th bain-marie pot with their laminated ID in the pot and a self-adhesive Avery label with EQSRef on the lid.

The HOT samples were cooked on the consumer serving day and the fabricated samples placed directly into 1/9th bain-marie pots together with their laminated ID. RHT and HOT samples were dispersed in EQSRef alphanumeric order across 5 bain-maries held at 50˚C until all product was served. Serving to consumers utilised MSA roast protocols which dictated serving order, time, and consumer allocation with the EQSRef bain marie labels cross checked against the plate labels as product was transferred from each pot. Two small slices were served for sliced forms and a constant volume for chopped or pulled product. As shown in Table 19 this resulted in 4 paired RHT and HOT samples from common muscles and positions within an animal being served in the same consumer session. The bodies in each pick also encompassed a controlled mix of grass, grain, PBR level and USA and Australian product.

As for all MSA consumer sensory protocols each consumer was served 7 samples with the first a common presumed mid quality link, utilising USDA Standard brisket at TTU. The following 6 samples served to each consumer were one from each of 6 products, created from muscle and serving form combinations and judged to be of different eating quality to ensure sensory range. In the Table 19 example the 6 products were constructed as a RHT and HOT sample of sliced, chopped, and pulled form. Products were served in accordance with a 6 x 6 Latin square order to ensure each was served an equal number of times in each serving order from 2nd to 7th and equally before and after each other product. Each sample was evaluated by 10 consumers.

The rib and navel brisket cooking and serving procedures were identical to that described for the point end brisket other than the different component muscles. The covering *M. serratus* muscle and *M.intercostales* muscles were separated from the rib bones after cooking and prepared as separate test products. Two muscles were also separated in the navel end briskets. Both the rib and navel end muscles were too small and of inappropriate shape to serve sliced and consequentially the chopped serving form was used for evaluation.

The cooking and serving procedures were replicated with paired samples at UNE utilising the primals from the 3 bodies within each PBR. As only one brisket was available per body these comparisons did not include a direct RHT to HOT within body comparison across countries. Further supplementary briskets were collected in conjunction with other cuts and utilised within the UNE testing to assess HOT versus RHT forms with Australian consumers and to assess cooking time and yield variation if briskets were cooked whole, as in the major trial, relative to the muscles being separated prior to cooking.

The Australian navel end briskets at TTU were further evaluated to compare TBQ cooking with TTU beef bacon and corned beef processes.

3.3.4.8. Freeze and thaw ageing.

A considerable volume of MSA graded product cannot be sold as MSA due it being frozen prior to the mandated 5 day minimum ageing period post slaughter. This restriction was adopted by MSA due to a lack of data at lesser ageing. In practice most plants need to closely balance chilled and frozen product volumes to achieve maximum throughput due to restricted capacity of either chill tunnels or plate freezers. A common result is that a high proportion of secondary cuts such as insides, outsides or chucks derived from MSA bodies may be frozen immediately after boning.

A pertinent question is whether these could be thawed at a destination and aged after a frozen period. Meat science theory largely agreed that the ageing process might continue after thawing providing freeze and thaw conditions were not severe enough to extensively disrupt cell structure.

A small exploratory study was conducted to establish if this was plausible given the well-controlled freezing procedures found in large scale export focussed plants. The study utilised paired cube rolls from 18 cattle selected from an MSA dairy kill and fed at a feedlot. The cube roll from one carcase side of each was required for the primary trial with the second tagged and frozen immediately after boning in a plate freezer following normal commercial practice. The chilled cube rolls were shipped to the CSU meat lab and fabricated into two MSA protocol grill samples within 72 hours of kill. One set of samples were frozen at the nominated 7 days ageing and the other at 21 days with position and ageing rotated for balance.

The paired (Fresh 7 and 21 days aged and frozen 7 and 21 days aged) samples were all consumer tested within common picks in conjunction with other MSA project samples to ensure linkage. In all the fresh and frozen pairs were distributed across 9 consumer picks (540 consumers) tested in multiple Northern NSW, mid coast NSW and Southern Sydney locations.

To achieve equivalent days ageing the frozen samples were removed from the freezer 6 and 20 days prior to sensory testing and thawed slowly in a 1˚C chiller. The standard sample pairs were posted frozen per protocol with plastic blocks placed where frozen product was allocated and thawed by placing in the same chiller 24 hours prior to testing. At the sensory venue each round sheet was opened and the plastic blocks replaced by the nominated frozen and thawed sample steaks after which sensory testing followed standard MSA protocol.

3.3.4.9. Evaluation of Northern and Southern grassfed product

Grassfed product was supplied by all plants within the group and ideally able to be supplied from alternate plants to capitalise on seasonal conditions with northern supply in winter offsetting generally restricted numbers in the south. Customer feedback however indicated that some believed the two differed substantially leading to some customers specifying supply from a particular plant. This was of concern and contrary to the desire to have uniform brand standards across all sites with interchangeable supply.

The questions arose prior to full application of the more sophisticated PBR settings creating uncertainty as to whether the perceived, or perhaps actual, difference related to a generally lower MQ4 related cattle population in the north relative to the south or an alternative scenario that flavour differences related to grass species might be responsible. Background analysis suggested that predicted MQ4 ranges did differ between the plants with the northern toward the lower cut off settings and the south somewhat above on average. The question also arose of whether such differences might be relevant to specific export markets and to potential nuances in their domestic production conditions.

To resolve these questions a “North / South” project was initiated in which cuts would be collected from northern and southern plants in two seasons and compared through MSA sensory and flavour chemistry evaluation. Tenderloin, cube roll, striploin, and rump primals were collected from both sides of 9 grass fed bodies at both plants after MSA grading to determine PBR, with 3 bodies from each of the Premium, Classic and Selected categories identified to ensure relatively balanced MQ4 ranges.

To examine whether any flavour based differences might be perceived differently by Irish or USA consumers, respectively more familiar with grass or grain fed product, in addition to an Australian consumer comparison, paired samples were designated for Australia, Europe (Ireland) and USA. This required sample preparation within the plants to retain export status for sample shipment.

Standard MSA protocols were used by the research team and company personnel within the boning room area with sample fabrication proceeding immediately after cut collection. Each cut was fully denuded, and the individual muscles separated in the tenderloin, cube roll and rump primals. The fabrication plan was developed with MSA CUD software which produced control and unique sample label files. Within the design allocation of country to position within each relevant muscle was balanced. All samples were aged 35 days to replicate export supply.

The butt tenderloins (TDR034) were packed as roasts and retained in Australia to provide needed MSA data. Two samples of the cube roll LD muscle (CUB045) and striploin (STR045) from each body were packed for Europe, USA, and Australia with the second sample allocated as link to ensure a consistent consumer starting sample. For the smaller tenderloin (TDR062) and larger portion of the rostbiff (RMP131) a single sample pair were allocated to Europe and USA. The spinalis muscle (CUB081) from the cube roll, rump cap (RMP005) and small rostbiff portion (RMP231) were only paired with USA for inclusion and linkage in other TTU based activity. The number of samples fabricated from each muscle by plant is presented in Table 20.

Table 20. Samples produced from muscles within plant and sensory test destination.

	DESTINATION				
Plant and Muscle	**AUS**	**EUR**	**RST**	**USA**	**Total**
Teys Naracoorte	**99**	**54**	**18**	**81**	**252**
CUB045	18	18		18	54
CUB081	9			9	18
RMP005	9			9	18
RMP131	18	9		9	36
RMP231	9			9	18
STR045	18	18		18	54
TDR034			18		18
TDR062	18	9		9	36
Teys Biloela	**99**	**54**	**18**	**81**	**252**
CUB045	18	18		18	**54**
CUB081	9			9	**18**
RMP005	9			9	**18**
RMP131	18	9		9	**36**
RMP231	9			9	**18**
STR045	18	18		18	**54**
TDR034			18		**18**
TDR062	18	9		9	**36**
Total	**198**	**108**	**36**	**162**	**504**

After fabrication the samples at each plant were packed in cut specific cartons for each destination. Individual EU stickers were placed on all EU samples. The cartons were then consolidated in an export registered Brisbane cold storage facility with the designated Australian cartons transferred to the UNE meat laboratory for inclusion in sensory testing.

Global COVID restrictions have held back testing in Ireland and USA to date with only the Australian samples tested. Two picks have been posted in Ireland and are programmed for consumer testing in October in conjunction with Irish samples from a major collaborative genetics project. It is planned that a similar mix be tested in USA utilising USDA Meat Animal Research Center samples from the same genetics project.

4 Results

Results are reported within the focus areas and for principal component projects in this section. In practice overall project success required extensive interaction between focus areas with these being interdependent. The consolidated impact, current operation and prospective future vision is addressed in the Discussion and Conclusions sections.

4.1 Focus Area 1 - Value Based Marketing (VBM) and Payment (VBP)

While it was no secret that there was significant variation between animals, the degree of variation and related $ value difference was unclear and often substantially underestimated within the beef industry at farm and processor level. The detailed VBM work within the group aimed to quantify the value distribution, examine the relative impact of different value contributors, and to consider how a transition to a value based livestock payment VBP structure might be practically delivered considering both logistical and cultural change would be required across sectors. Fig. 19 provides a conceptual view of value components.

Figure 19. Conceptual construction of carcase value components

Fig. 19 illustrates the major value contributors within a framework that firstly allocates cuts or muscles to differentiated eating quality bands with related pricing. This was recognised as a core criterion likely to heavily influence the balance of importance between yield, the determiner of actual weight to be sold, and consumer satisfaction being the driver of $/Kg for INDIVIDUAL portions marketed under a VBM structure. It was presumed that for a manufacturing type carcase, essentially with all muscles packed as trimmings, that virtually all value would relate to yield differences whereas the consumer eating quality outcome would become a larger factor as carcase quality increased.

Provenance or brand criteria such as HGPFRE, Free Range, Grainfed or Angus could also impact value independent of both yield and eating quality. Similarly, market eligibility often related to potential pricing premiums as did pragmatic livestock purchasing activity related to volume, availability during a tight season and longstanding relationships. It was also recognised that co-products represented further value variation, but this was excluded from immediate consideration due to the need for effective measurement systems at individual body level.

The expected difference in value contribution was supported by prior data gathered through the Polkinghornes system under which individual cut, fat and bone weights had been collected on over 5,000 head and then retailed on a strict MSA based 3*, 4*, 5* pricing basis. Table 21 displays summary data provided as producer feedback from a fully transparent VBM structure for a group of 12 visually similar young British breed cattle.

Table 21. VBM Feedback for consignment of 12 head (courtesy Polkinghornes Pty Ltd)

Polkinghornes Fresh Pty Ltd Value & Performance Analysis						Summary Sheet						Head	12	Killed	17-Mar-08		from Supplier	3972 R J Polkinghorne & J C Philpott		
												Inv	1075	Paid	27-Mar-08		Av $ Kg	$3.14	Total Nett Paid	$7,523.54
$ Kg & ID			Graded Weight as % of HSCW								Yield	Graded Value Analysis in $								
$ per Kg of HSCW	Ear Tag	Body No.	Ungrd	3 Star	4 Star	5 Star	Trim	Fat	Bone	NFS		Ungrd	3 Star	4 Star	5 Star	Trim	Fat	Bone	NFS	Total
$3.30	285	32	0.0%	11.8%	10.4%	1.2%	48.0%	11.3%	16.9%	0.0%	71.4%	$0	$138	$228	$38	$239	$0.62	$0.63	$0	$644.15
$3.29	1	37	0.9%	12.2%	9.4%	1.9%	48.5%	9.1%	17.5%	0.0%	72.8%	$9	$146	$204	$63	$220	$0.45	$0.66	$0	$644.42
$3.27	33	39	0.9%	11.6%	9.5%	2.0%	47.6%	11.1%	17.3%	0.0%	71.5%	$10	$148	$221	$70	$229	$0.64	$0.69	$0	$679.30
$3.24	5	31	0.0%	10.4%	11.6%	1.1%	41.8%	16.2%	17.1%	0.0%	64.9%	$0	$121	$257	$37	$222	$1.00	$0.65	$0	$639.14
$3.24	47	28	1.0%	11.9%	9.4%	2.0%	46.4%	12.5%	16.7%	0.0%	70.7%	$11	$149	$211	$70	$220	$0.74	$0.65	$0	$661.59
$3.23	3	34	0.9%	11.9%	8.3%	1.9%	51.0%	10.5%	15.2%	0.0%	74.1%	$9	$133	$172	$59	$217	$0.55	$0.53	$0	$591.40
$3.15	239	38	1.0%	9.6%	10.0%	1.9%	47.1%	12.8%	17.5%	0.0%	69.7%	$11	$119	$227	$68	$227	$0.76	$0.70	$0	$654.61
$3.10	343	30	1.0%	12.1%	8.0%	1.8%	48.0%	10.4%	17.1%	0.0%	70.9%	$12	$165	$199	$67	$248	$0.63	$0.73	$0	$690.75
$3.09	248	29	1.1%	12.6%	9.2%	1.9%	36.8%	19.7%	16.4%	0.0%	61.7%	$12	$162	$216	$68	$189	$1.36	$0.66	$0	$648.92
$3.03	332	33	0.9%	11.5%	8.7%	1.2%	45.6%	15.7%	15.7%	0.0%	68.0%	$8	$115	$169	$33	$177	$0.81	$0.50	$0	$503.69
$2.97	251	35	1.0%	7.6%	11.9%	1.8%	46.6%	13.7%	17.2%	0.0%	68.9%	$11	$94	$226	$64	$227	$0.84	$0.70	$0	$623.93
$2.76	60	36	0.9%	11.2%	7.6%	1.6%	36.2%	22.2%	16.5%	0.0%	57.7%	$10	$134	$175	$54	$167	$1.46	$0.62	$0	$541.64
AVERAGES			0.8%	11.2%	9.7%	1.7%	46.1%	13.0%	16.8%	0.0%	69.5%	$8	$136	$212	$58	$220	$0.76	$0.65	$0	$634.72
		Min	0.0%	7.6%	7.6%	1.1%	36.2%	9.1%	15.2%	0.0%	57.7%									
		Max	1.1%	12.6%	11.9%	2.0%	51.0%	22.2%	17.5%	0.0%	74.1%									

As displayed in Table 21 even in a group of 12 very similar appearing cattle there were large differences in value, representing a $0.50 / kg HSCW range on the values at the time (2008). The interaction of yield and eating quality pricing is also evident with the highest yielding body not the highest value although yield appeared to drive the lowest value body, in this instance due to the extreme 22% fat content. Similarly, the actual weights of 3*, 4*, 5* cuts and trim vary across the ranking, interacting with yield. In this integrated system pricing was based on a 6 week rolling average for each component with distribution working back from final sales $, essentially all retail POS other than fat and bone. Distribution was set at 66% of retail value to the boning room and 66% of the boning room revenue passed through to the cattle supplier, effectively 43% of retail. This process had been observed to change attitudes and practices quickly and substantially at both boning room and farm level, similar in fact to that observed with the introduction of component payment in the dairy industry.

The hypothesis behind VBM adoption was that a commercial "win-win" would result from higher performing cattle generating higher returns for similar production cost at farm and processing.

Fig. 20, also from Polkinghornes feedback, provides a graphic display for one carcase, highlighting the difference in value for major carcase components, the pie chart to the left being weight and that to the right $.

Polkinghornes Fresh Pty Ltd
Value and Performance

Supplied by:- 3972 R J Polkinghorne & J C Philpott

Ear Tag 1
Body No. 37

Comments:-

NLIS	Kill Date	Works	Chain	Body No	Breed	EPBI	Sex	HGP	Yield	$ per Kg	Total $
0	17-Mar			37		0	M		73%	$3.29	$644.42

MFV	SaleYard	Rn/Flsh	HSCW	Hang	Hump	Uoss	Umb	Rib Fat	Ult pH	UltLTmp	EMA	Ribed	MtCol	FtCol	P8 Fat
N	N		196	TX	50	110	290	3	5.60	3.7	58	10	3	2	

Grade Weight Percentage of HSCW								Value of Product by Grade							
Ungrd	3 Star	4 Star	5 Star	Trim	Fat	Bone	N.F.S.	Ungrd	3 Star	4 Star	5 Star	Trim	Fat	Bones	N.F.S.
0.9%	12.2%	9.4%	1.9%	48.5%	9.1%	17.5%	0.0%	$9.02	$146.35	$204.13	$63.33	$220.48	$0.45	$0.66	$0.00

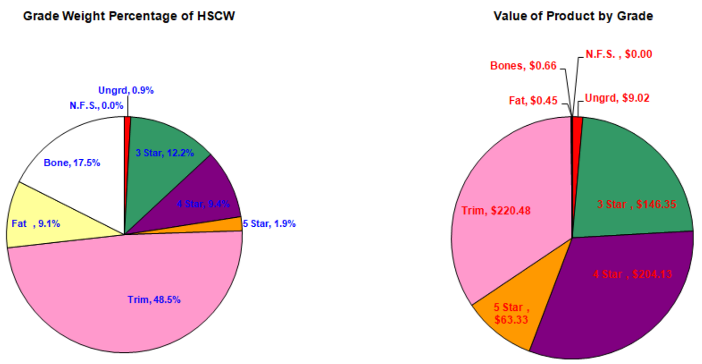


Figure 20. Graphic comparison of weight and value distribution for one carcase (courtesy Polkinghornes Pty Ltd)

Further indication of significant livestock value differences and their impact on feedlot profitability was provided by the well-established feedlot trial run at Jindalee feedlot on an annual basis. Under this format producers entered groups of 10 cattle which were fed together and slaughtered together. Results had consistently indicated greater than $200 / head profitability differences with an example displayed in Fig. 21. This trial program had been very well supported over a number of years and generated strong producer involvement and interest.

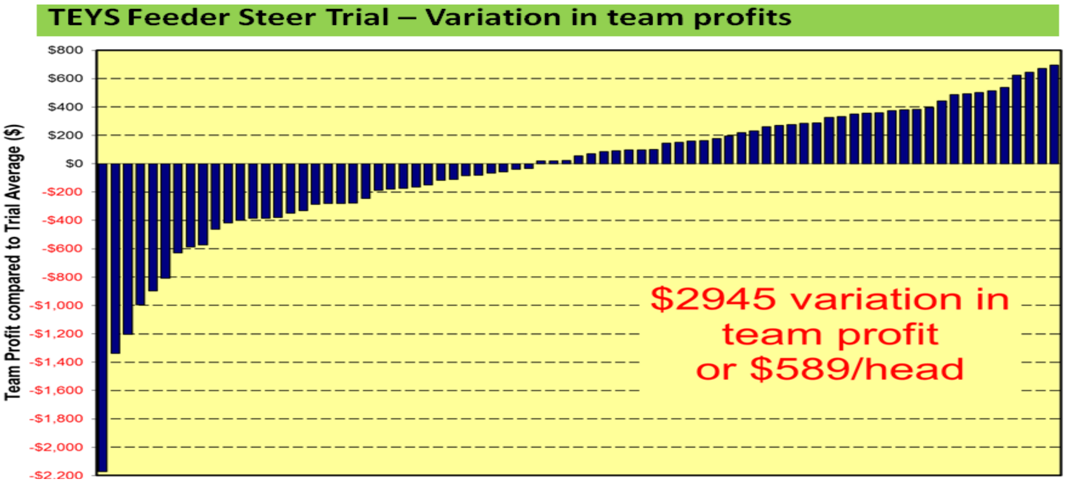


Figure 21. Team profit comparisons from feedlot trial

The challenge at scale was firstly to determine actual value differences in the cattle population, requiring estimates of yield rather than direct measurement, and to develop both practical systems and software algorithms to calculate value and communications that could positively impact both supplier and plant cultures.

4.1.1. Communication of VBP principles and concept

The possibility of moving over time to a VBP cattle pricing structure was canvassed widely across the broader industry, with supplier organisations, key suppliers and within the business to gauge reaction and identify positive and negative feedback. The desire and logic of moving toward a Value Based trading system was introduced at very high industry and Government level though a senior manager ABARE presentation and extended through producer field days and in discussion with Industry organisations.

These presentations and subsequent discussion contributed to a broader understanding of the complexity involved in marketing beef, particularly at supplier level, but also inversely in producers highlighting their challenges in balancing genetics and management within climatic variation. While beef processing was regarded as "manufacturing" it was highlighted that in fact it was very different to other manufacturing processes where only needed components were purchased to make a defined product. Beef processors had to buy a product and then sell all the components in proportions dictated by biology rather than market demand, as presented in Fig. 22, and further complicated by being a perishable product requiring refrigerated storage and distribution across global markets.

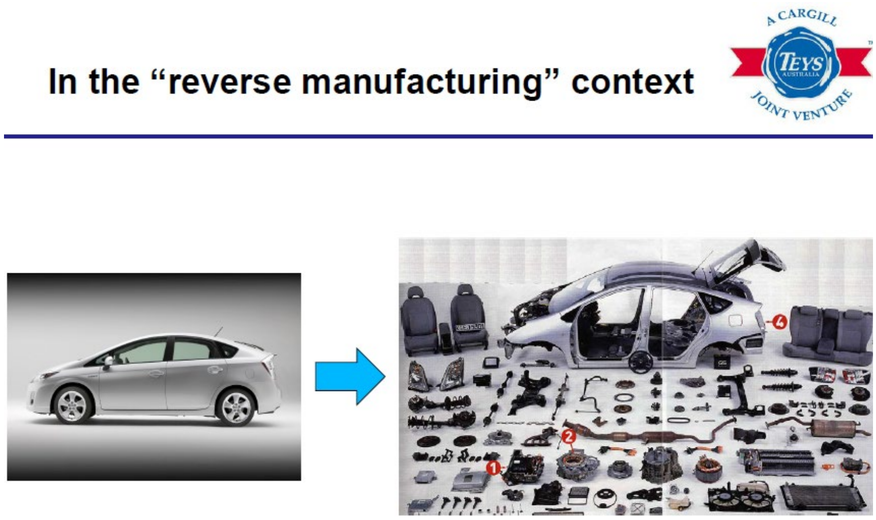


Figure 22. Reverse manufacturing context. Purchasing cattle to sell all components in balance.

Presentations were also made to the livestock buyers by Birkenwood, together with extensive workshopping and relaying of analysis results with management. The outcome was a clear interest in the concept from suppliers who in general saw merit in clear value communication which they could act on to deliver a higher value product. This attitude appeared strongest in the more professional sector of the industry where "measurement and management" were well used tools. Some scepticism was also noted among producers who suspected "it was just another way to get them" and among some livestock staff who perhaps felt threatened by a move toward more objective data driven valuation at the expense of negotiation skills. There was also concern as to the net impact on supply and reaction of opposition processors and saleyard marketers; would the better producers come across in greater numbers due to superior returns and outweigh potential losses through conservatives who distrusted the system or who received lower returns as VBM replaced average value approaches?

The consensus however was that the project should proceed to evaluate the data in depth and that industry discussion should be maintained while developing prospective delivery mechanisms and communication. It was presumed that pilot studies utilising selected suppliers and company owned cattle would provide an interim step ahead of any full transition.

4.1.2. Yield estimation

Given yield is a critical component of any VBM approach a first step in establishing a system was to evaluate potential yield direct measurement or estimation alternatives. A presentation covering aspects of yield and quality estimates was made by Professor John Thompson and Rod Polkinghorne. Professor Thompson had utilised data from a VIAscan trial that include detailed bone-out data to compare yield estimation utilising various measures (Fig. 23). The purchase grid measures resulted in significant error with considerable potential improvement from the VIAscan vision system being trialled at the time.

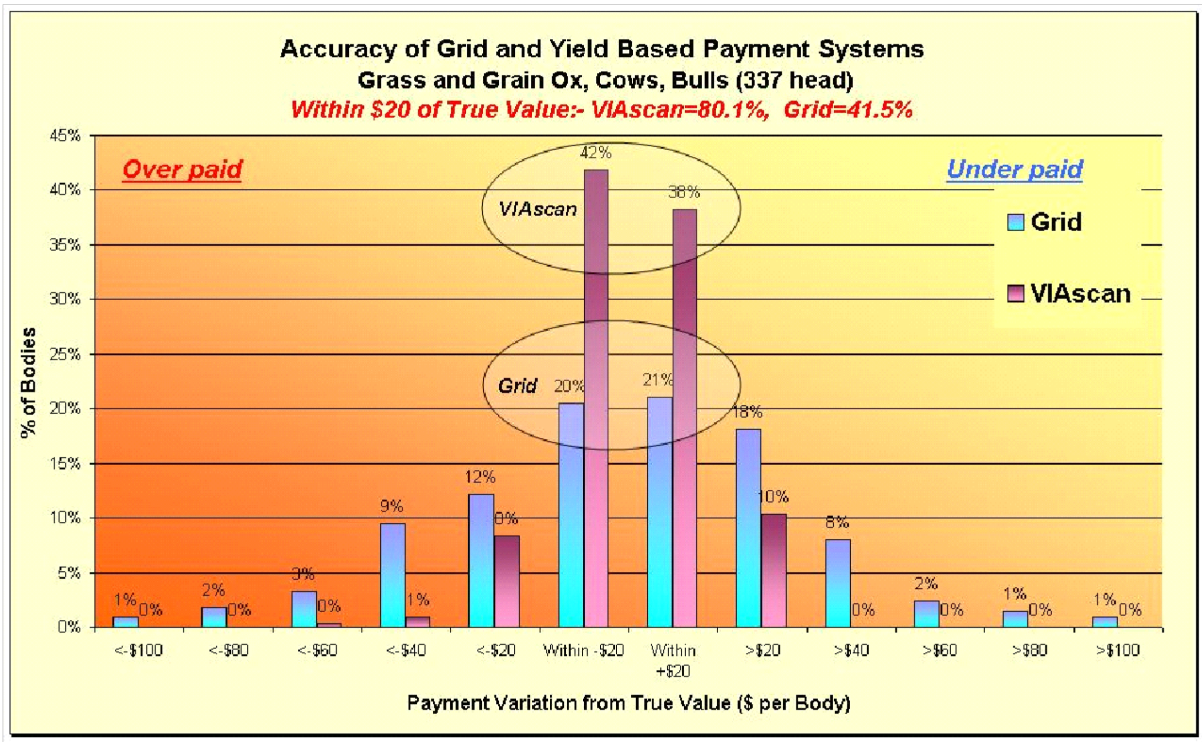


Figure 23. Yield estimate comparison using carcase grid measures relative to VIAscan.

The VIAscan option had been discarded as impractical at the time but offered encouragement that more recent vision technologies, including DEXA and CT scanning, may provide a solution in the medium term. While the conventional industry purchase grid base of HSCW, P8 fat, sex and butt shape was found to be an extremely poor predictor, analysis indicated substantial improvement if one or several cuts were actually weighed and included in the calculation with carcase measures. Calculations which included large body portions, such as a butt, improved accuracy as did addition of individual cut weights which improved prediction from an unsatisfactory base of 0.462 to a respectable 0.742.

The potential to include suitable weights in a commercial boning room was canvassed, including the possibility of installing a loadcell in the side chain to automatically weigh the butt after all loin and FQ cuts had been removed. After checking space and logistical issues required to ensure an accurate weight it was advised that this approach was not commercially viable. The option of measuring one or more larger cuts was also evaluated, with MSA research data indicating that lean meat cut weights were sufficiently correlated as depicted in Fig. 24.

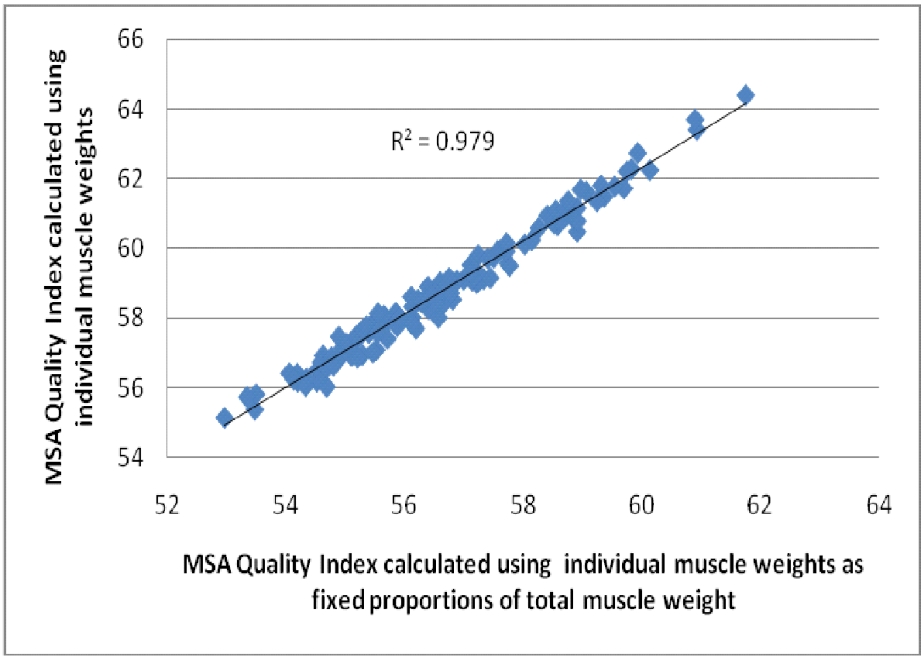


Figure 24. Relationship of actual individual muscle weights and calculation by a standard %

This approach was also considered problematic due to two factors: the requirement to reliably relate a muscle to the correct side and difficulties related to the wide range of trim specifications and cutting lines for most primal cuts. The difficulty of developing, and more so communicating, yield differences resulting from changed cut specifications resulted in the conclusion that yield should be estimated on a lean (LMY) rather than saleable (SMY) basis as this would provide a common comparison base at all levels including in producer payment. This did however require sufficient well controlled yield testing across cattle types in each location to generate reliable relationships between each cut specification and LMY to relate an LMY price to actual sales pricing or vice versa.

The adopted measure was a yield prediction equation developed from research data by Murdoch University. The equations adopted were:

For Steers

Predicted LMY = 62.1109 + (LeftsideHSCW x -0.09244) + (EMA x 0.1645) + (RibFat x -0.4936)

For Heifers

Predicted LMY = 59.3974 + (LeftsideHSCW x -0.09244) + (EMA x 0.1645) + (RibFat x -0.4936)

These formulae had been shown to provide sufficiently accurate estimates to be commercially useful, surpassing the existing grid measures by a considerable margin. The predicted CT lean in the training data sets versus left side HSCW is displayed in Fig. 25. The individual dots are residuals of the prediction model from the response surface with colours representing data-set of origin.

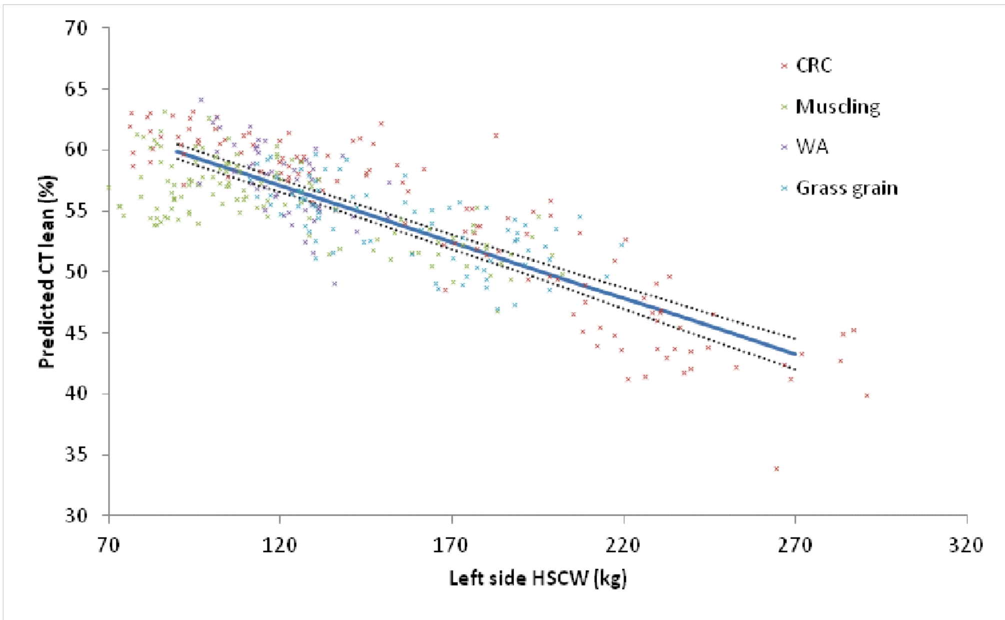


Figure 25. Prediction accuracy of "Murdoch" LMY equations (R2 = 0.71 and RMSE = 2.79)

The selected equations required inputs of left side HSCW, eye muscle area (EMA) and ribfat. To lessen the potential variation from different side weights total HSCW/2 was utilised in the applied version. Accurate HSCW was readily available from the system as was ribfat and EMA through the MSA grading data. From observation however, and a study of data patterns, the accuracy of the EMA measure was believed questionable as accurate counting of the squares in the standard EMA grid required some time and attention to detail that might be challenging under standard grading conditions.

To assess this risk a survey was conducted over 5 days production. Two Texas Tech intern students with extensive meat judging experience independently measured EMA from both sides of 286 carcasses to generate data on the inherent variation between sides with the plots presented in Fig. 26. The correlation was 0.7 establishing that any measurement of EMA would be less than perfect, although useful in the absence of a superior yield measure.

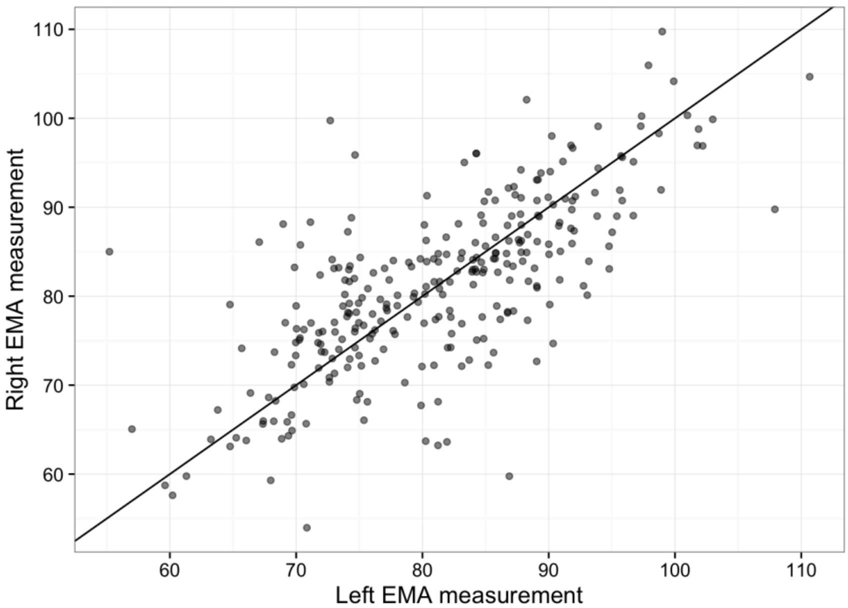


Figure 26. Comparison of EMA from right and left sides of 286 carcasses

They also independently assessed the graded side of the 3,863 head graded over the 5 day period which was then compared to the plant grading data. While minimum and maximum differences within each day were in the order of +/- 30 cm^2 the mean differences were within 5 cm^2 and the range between the first and third quartile values typically within 10 cm^2. Fig. 27 displays the correlation of 0.62 (R^2 = 0.38) between the plant graders and external TTU reference.

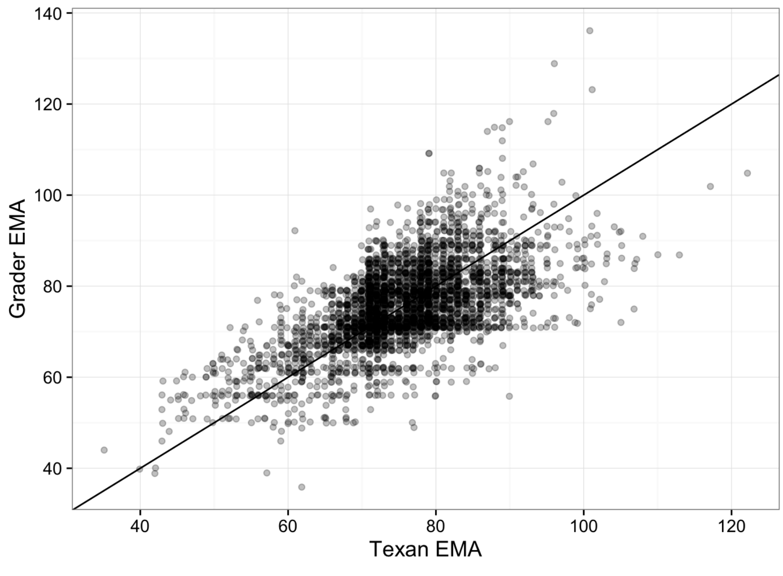


Figure 27. Correlation of plant grader and TTU EMA measurements

Further analysis evaluated the economic impact of EMA measurement variation with the correlation between the grader VBM and TTU VBM 0.97 for $/head which, while high, still resulted in appreciable differences. Fig. 28 illustrated the $/Kg HSCW variation that would result from measurements with a standard deviation of 7, close to that observed, and 14 for reference.

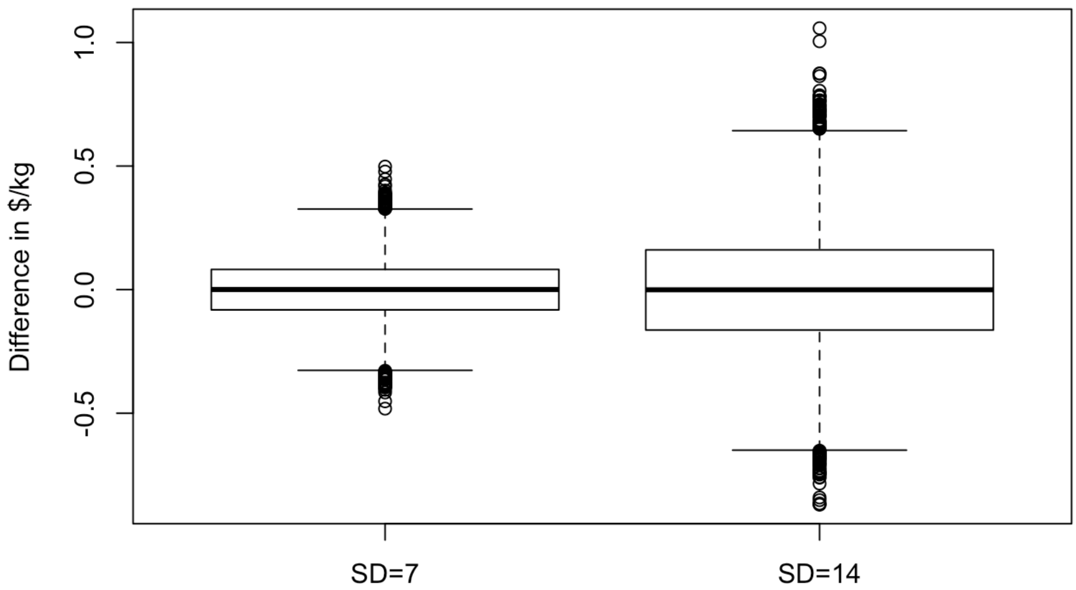


Figure 28. Impact of EMA accuracy on VBM $/Kg with Std.Dev. of 7 or 14

While far greater than desired this variance was not overly surprising and management action was initiated to ensure more attention to the EMA measurement across all sites. Checks were also made to assess the impact of a 10 cm^2 +/- EMA with the result indicating a typical 3 to5 kg LM impact. It was also anticipated that improved accuracy would be provided in the short term by adoption of objective REA measurement by the E+V or alternative appraisal systems as observed in the evaluation studies. Finally, the range of EMA at 4 plants was examined with distributions shown in Fig. 29.

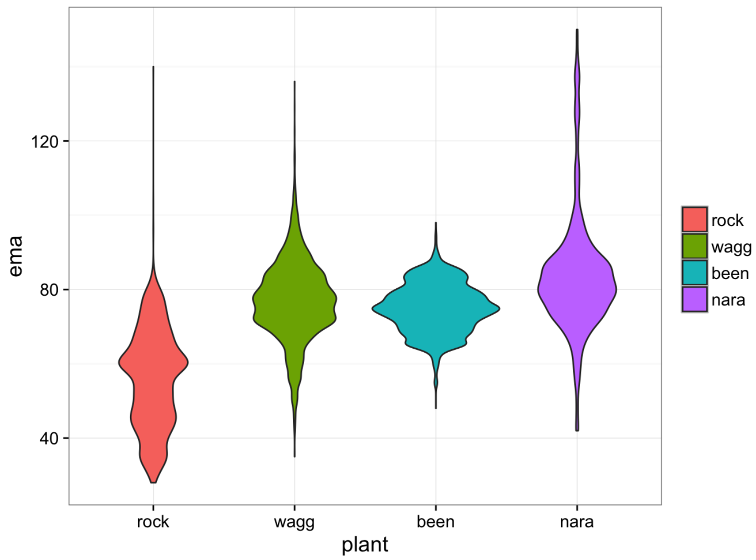


Figure 29. Eye muscle area distribution by plant

4.1.3. Combining Eating Quality estimation with Yield

The MSA model produces a predicted MQ4 score for every muscle in the prediction model at the time of grading, in turn adjusted to reflect alternative cooking methods and days of ageing. The MSA Index assumes a standard yield % and cooking method for the 39 muscles in the Index. It then takes the MQ4 score for a selected cooking method for each muscle aged 5 days and from an AT suspended carcase and multiplies each MQ4 score by the standard yield. These are then added to produce the MSA Index, in effect a standard yield weighted MQ4 average for the carcase.

The Index consequently provided a single score EQ measure that was considered for possible utilisation in conjunction with estimated lean meat Kg. This approach was rejected however due to the extensive variance from brand settings. While the Index served as an excellent benchmark for producers it represented a carcase potential under strict standards of a specific cooking method for each muscle, AT hang and 5 days ageing. Of these factors the only constant for actual practice was AT hang meaning that any payment on Index would not be directly related to true value. An alternative "Value Index" was constructed in which the cooking methods and days ageing applied within each new PBR were utilised and compared to the MSA Index. The differences were substantial and indicated that use of the MSA Index as either a direct payment option or in conjunction with LM Kg would create inaccurate and potentially misleading value signals to the producer, as shown for the previous MSA Boning Groups, and create risk for the business due to misalignment with actual product returns. An early conceptual framework is shown in Fig. 30.

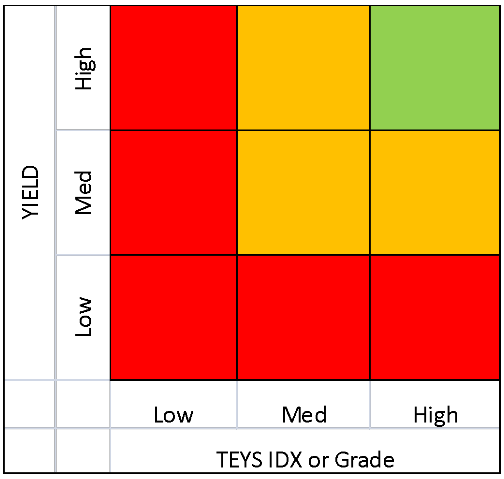


Figure 30. Early VBP concept utilising predicted yield and Quality Index

As illustrated the green cell represented peak value with high yield and eating quality with gold cells less value due to a combination of either lower yield or eating quality, and the red cells most undesirable. This principle was later adopted with MSA Index on the x axis for producer feedback and considered appropriate in this context as a consistent indicator of carcase merit.

To better relate true value to the business the EQ pricing base had to reflect actual market returns rather than potential, even when a brand specific Index was utilised. The ideal measure of this was actual sales values, with the complication relating to the challenge of linking them to individual body cut and trim values. As the EQ based PBR were developed to support the branding strategy the assigned PBR offered a solution if revenue could be tracked to PBR, ideally though actual boning room records. The IT group initiated changes to provide this capacity within the Uniworks system through later upgrades.

VBM analysis was commenced prior to adoption of the Murdoch yield formula. An initial Birkenwood PBR prototype developed to assess potential revenue differences from segregated EQ categories utilised conceptual EQ based categories of Platinum, Gold and Silver incorporating 28 muscle settings. Birkenwood software was utilised to calculate individual cut MQ4 scores for all MSA eligible cattle from the 5 plants for grass and grain fed categories over a 12 month period in monthly increments. Individual cut counts within each MQ4 score from 1 to 100 cut were used to establish MQ4 score ranges for each quality category and settings developed from multiple analyses. Head counts within Best, Better, Good, and ungraded were then calculated for each month within plant and extended to number of cuts. Agreed standard yields were then applied to average monthly grass and grain HSCW records for each plant through a complex Excel based model to calculate estimated weights.

These cut weights were extended by alternative pricing scenarios for each cut. The same models were run for the MSA Boning group categories and revenue compared. The calculated revenue substantially exceeded the existing structure with the gains relating to differential individual cut pricing within each PBR. For most analyses it was assumed that the current cut prices represented entry level (Good) equivalence with the Better and Best attracting premiums. Alternative scenarios were modelled using pricing suggested by sales staff and by applying progressive % steps and included discounting of the Good category or leveraging from the Ungraded base. In all cases revenue projections were positive and obviously related to the pricing assumptions used.

The Birkenwood software provided the ability to load and analyse bulk data from actual production and extend analysis to plant populations. More comprehensive VBM estimates were generated with introduction of the Murdoch yield formula and agreement of PBR settings for use in a full production trial. These calculations extended the standard yield data to individual body estimates of lean meat Kg and allocated each carcase to a PBR utilising the Birkenwood system.

To enable clear value comparison it was decided to compare individual carcasses within a common total $ pool with this being the total actual monthly livestock purchase cost for each plant. As discussed in the methodology section, a number of VBM pricing alternatives were calculated and evaluated ranging from entirely LM Kg to only MSA Index to gain an appreciation of the relative contribution of yield and quality.

Regardless of the measure considered or the plant location, it was clear that individual animal value varied widely with actual livestock payments routinely in the order of $0.50/Kg HSCW above or below true value. As livestock values have effectively doubled since this time current differences could also be expected to be larger. Statistical analysis was conducted across all plants for a reference month by Dr Garth Tarr. Similar variation was found within each plant as displayed in Fig. 31 with the thickness of each violin plot indicating the number of head at each value.

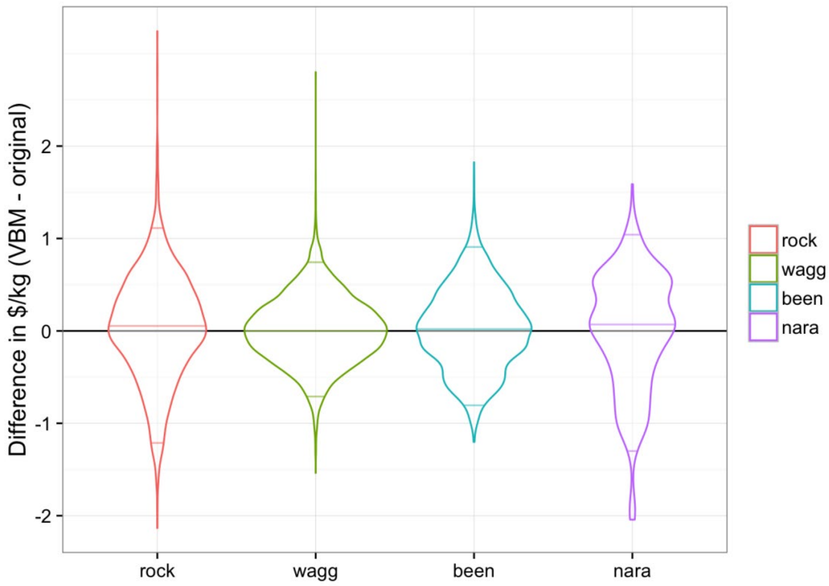


Figure 31. Differences between VBM value and actual livestock payment by plant

Similar differences were observed between and within mobs as illustrated by Fig. 32 with significant overlap indicating that all had an extended range.

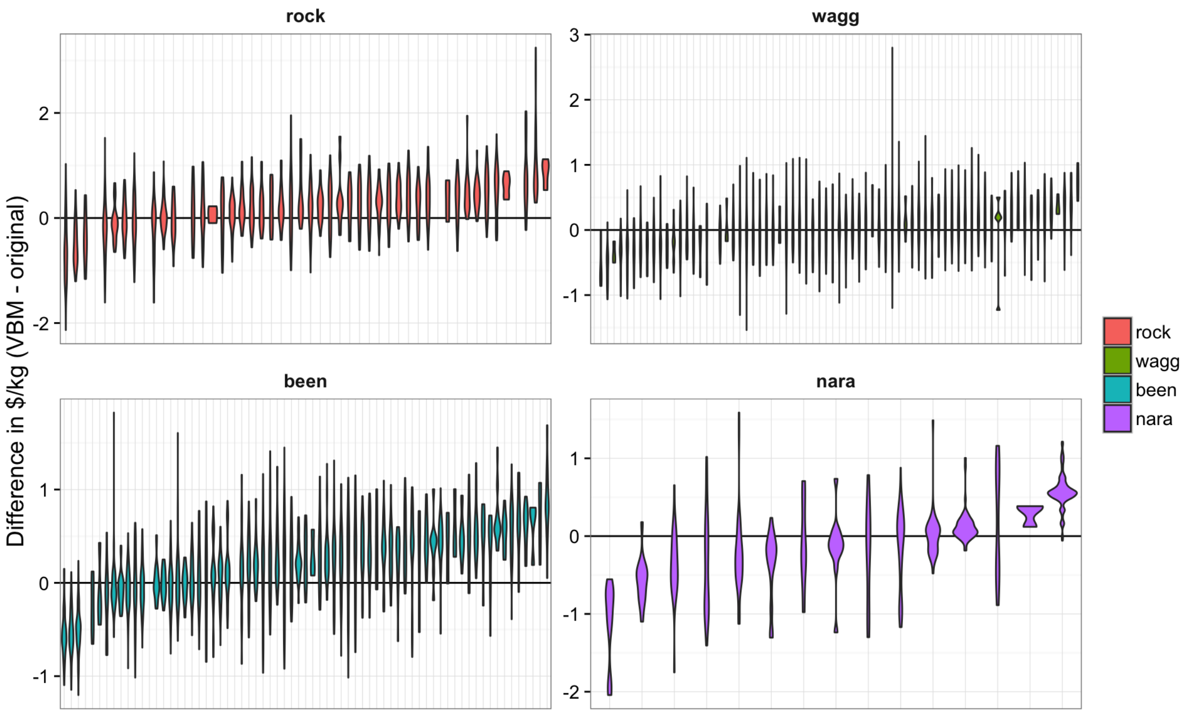


Figure 32. Differences between VBP value and actual livestock payment by mob and plant

Dr Tarr also evaluated MSA grader within each plant and concluded that there was no evident grader impact on the observed distributions. Fig. 33 illustrated more extreme distribution of consignment means for a selection of mobs at each plant with the dot size indicating the number of head. While

Fig. 32 indicated considerable overlap of individual values in each mob it was also clear that some consignments were more extreme which could result in larger differences between VBP and existing payment systems.

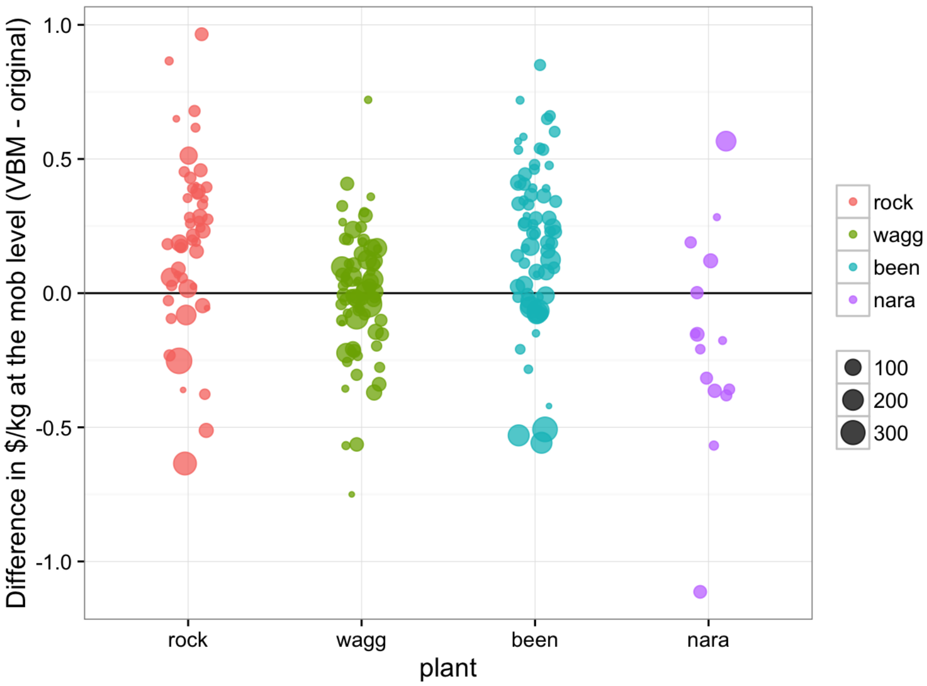


Figure 33. Average VBP difference ($/Kg HSCW) for representative mobs

Individual animal variation within a selection of consignments is illustrated in Fig. 34 with the horizontal bars representing the consignment means.

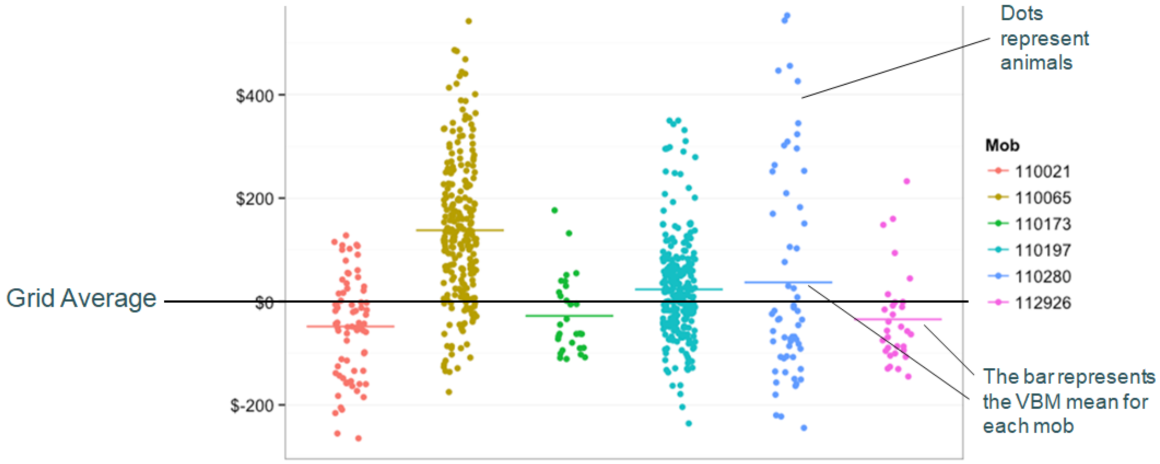


Figure 34. Individual animal VBP variation within mob

The principles adopted in this analysis were further refined in conjunction with the transition to the MSA V2.0 model and commercial implementation of the updated branding strategy and supporting PBR structure. The number of cuts in the new PBR were expanded to 43 and with further cooking methods employed and combined with modified ageing days including extension to 50 days for some muscles with an eye to export shipment timeframes. The later work, supported by software enhancement, adjusted the gross individual animal purchase payments for non-EQ and yield parameters such as breed or brand provenance issues to ensure that VBP relationships were separated from other value contributions.

For these VBP analyses the actual adjusted livestock purchase costs were aggregated within PBR which enabled actual PBR values to be utilised as opposed to theoretical modelling. The Murdoch formula continued to generate the LMY Kg component.

With these changes new R based Shiny App applications were developed by Dr Holly Cuthbertson and Dr Garth Tarr to allow instantaneous loading and calculation of VBP comparisons from selected files produced using the filtering procedures within the Birkenwood Maximiser software together with graphical and numeric analysis functions of a quality that could be commercially applied should this be desired.

4.1.4. VBP pricing grids and feedback

From the initial pre contract discussions an integrated system for relating quality and yield into a true value based combination was advocated, with the broad concept progressively refined over time with the benefit of substantial data, statistical and general analysis, bespoke software including R Shiny App based tools and, critically, extensive discussion over an extended period with key managers and staff throughout the plant and head office functional areas. An early concept presented in an initial presentation by Prof John Thompson and Rod Polkinghorne is presented in Fig. 35 and envisaged saleable meat yield estimation by a mix of carcase measurements and weighing of carcase portions and selected trimmed cuts within the boning room. A value index was proposed combining an MSA based Quality Index with SMY estimates.

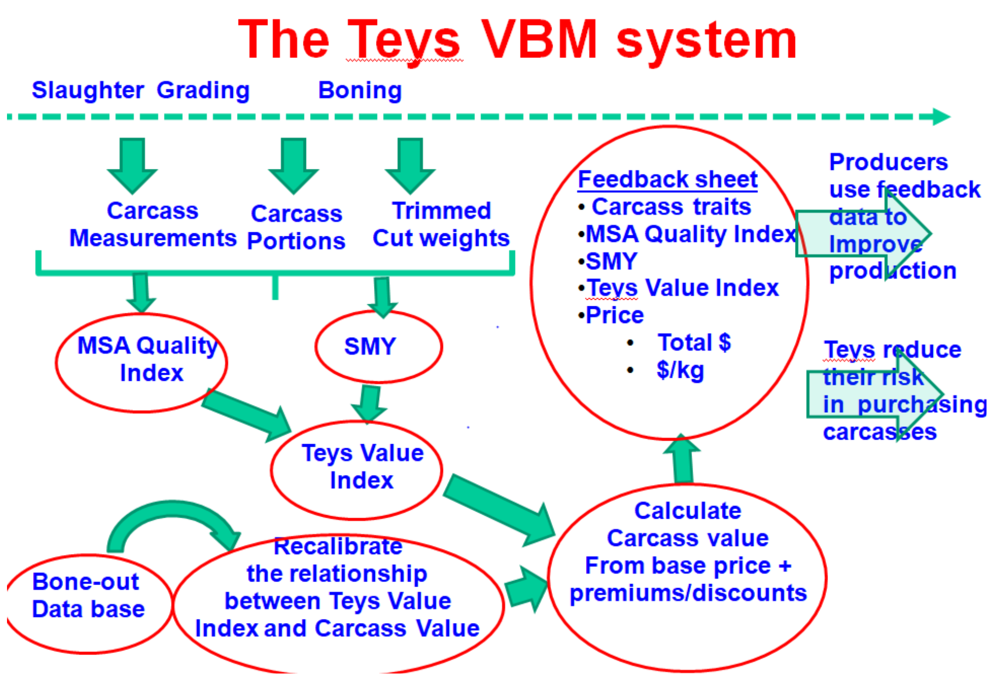


Figure 35. An early VBM system concept

Clear communication that provided actionable information and a readily understood explanation of the various value components was regarded as an essential component of the VBM work program. Detailed discussion was held with staff involved in setting and adjusting the company livestock purchasing grids to better understand the underlying rules applied and the relationship of these to operational or marketing value differences.

The "rules" proved to be complex with numerous individual complexities relating to whether certain premiums were additive or if only the highest eligible price was paid. As an example, the following was understood to apply for various EU eligible groupings:

- To be eligible for EU all these conditions must be met: EU eligible (EU assessment), HSCW between 240 and 420 kg, dentition 0 to 4, meat colour and fat colour 4 or less.
- If EU and organic the premiums are additive.
- If EU and Angus the highest price of EU/Angus is paid on the day, but they are not additive. (Requires breed of ANG).
- If EU and Grasslands the highest price of EU/Grasslands on the day is paid but they are not additive. (Requires assessment of CPF or FR in addition to all the EU criteria).

These conditions were in addition to P8 fat, bruising and HGPFRE making interpretation of the grid challenging for many suppliers with some producer comment that the grid complexity "always resulted in discounts" leading to a degree of suspicion.

4.1.5. Development for the MSA V2.0 model and refined branding strategy

With the introduction of a new and significantly upgraded MSA prediction model the branding and PBR structures were extensively reviewed and adapted in conjunction with a major enhancement of the Birkenwood software system, including developing interaction with the IT system to facilitate and automate data exchange and calculation. The impact of these changes on VBM and VBP calculation and results was studied in detail utilising the most recent 12 months of data, including parallel evaluation with the previous model base for a 6 month prior period.

The VBP calculations were modified with a more extensive R Shiny App framework developed to provide a direct upload of Birkenwood files and allow live adjustment of price components that were not yield or eating quality (EQ) related. These included market eligibility premiums and brand provenance criteria including Angus, Free Range, and other factors. These adjustments ensured that VBP comparisons were not impacted by other value components. The analysis capability of the web-based software was also significantly upgraded to a standard thought suitable for live commercial application in analysing VBP impacts and producing web based company or producer feedback.

The new software application was utilised in analysing VBM and VBP data related to the new brand PBR settings and is described in the following section.

4.1.5.1. Summary of VBM and VBP analysis software App

'Upload Data' Tab

This tab provided the ability to upload a csv data file for processing. Once uploaded the data could be filtered using the 'Select Data' window to specify:

- Processors or plants
- Producers
- PBRs
- Kill dates.

The 'Data Overview' window, displayed in Fig. 36, listed the advice codes and number of head.

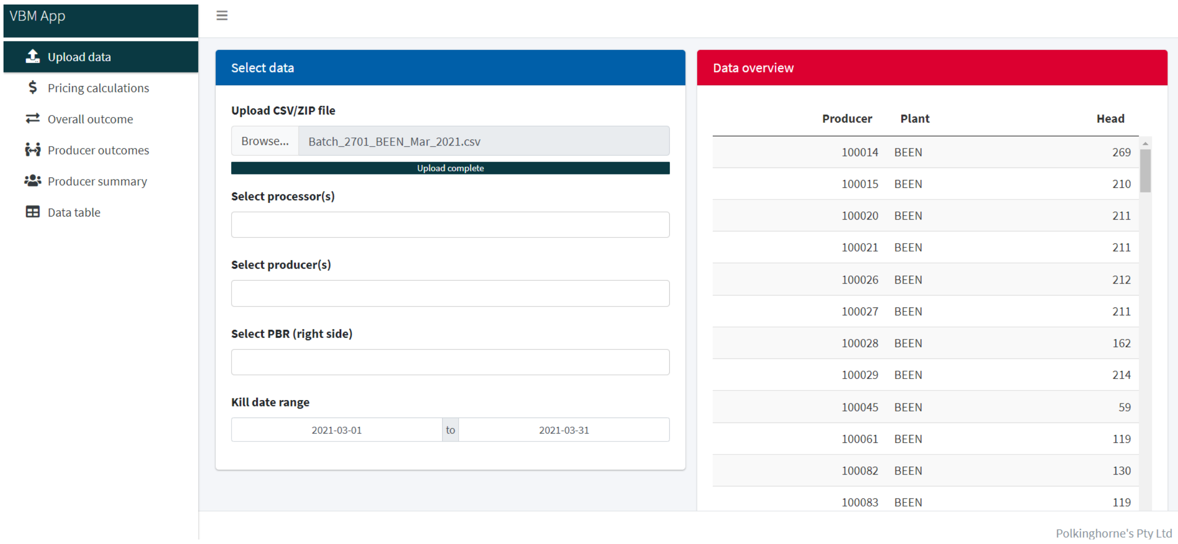


Figure 36. Screenshot of VBM Shiny App 'Upload Data' tab

'Pricing Calculations' Tab

The 'Pricing adjustments' window allowed for grid premiums to be taken out before VBM calculations occurred, so that only $ related directly to yield or eating quality were redistributed across the population. Once PBR prices were established these premiums were added back.

As shown in Fig.37 premiums of (Angus =20c/HSCW Kg) are deducted with the multiple sliding scales providing an instant recalculation when moved enabling both easy changes to actual grids or evaluation of possible adjustments.

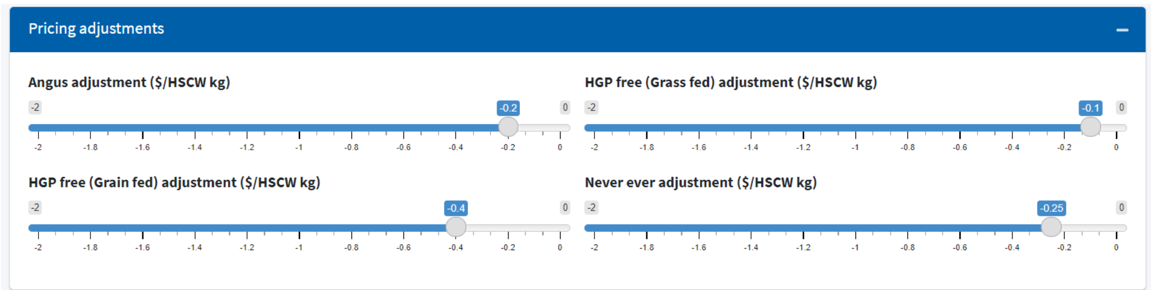


Figure 37. Screenshot of 'Pricing adjustments' window

'Overall Outcome' Tab

This tab summarised the payments for the entire population. The 'Paid difference summary' window displayed the distribution of payments across the overall population (Fig. 38) or within PBRs (Fig. 39).

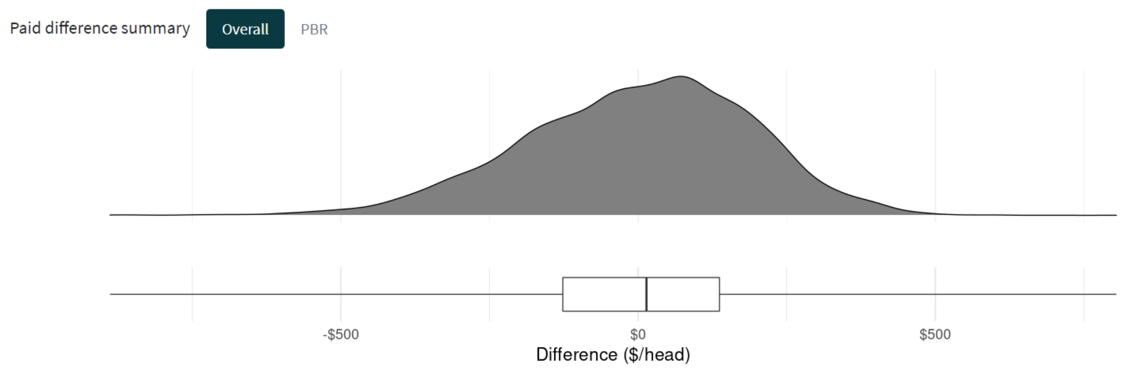


Figure 38. Screenshot of Overall 'Paid difference summary' window distribution graph

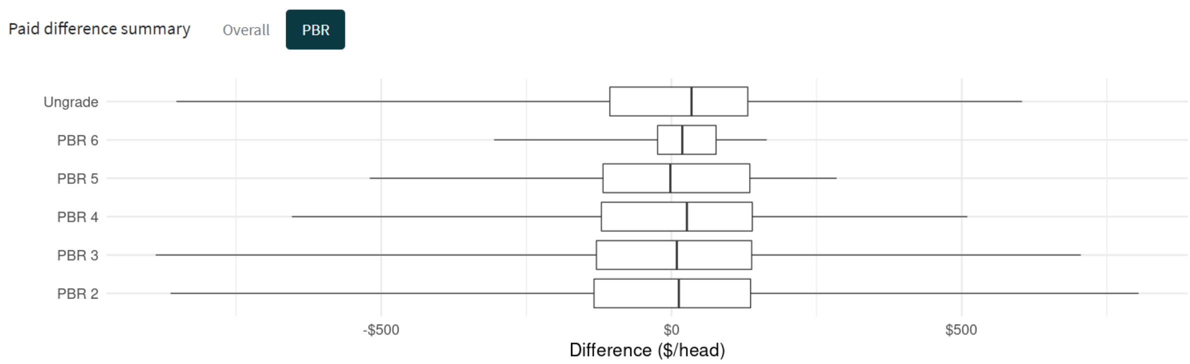


Figure 39. Screenshot of Overall 'Paid difference summary' window distribution graph

The 'Differences' tables, below the graphs on the actual screen, represented the exact numbers behind these graphs. Results are shown in both $ per head (Table 22) and $ per Kg/HSCW (Table 23).

Table 22. Screenshot of 'Differences' summary table by PBR and $ per/head

Differences

PBR	Min (Overpaid)	1%	5%	Q1	Mean	Q3	95%	99%	Max (Underpaid)
PBR 2	-$862.84	-$468.65	-$334.77	-$133.38	-$0.00	$136.31	$295.44	$420.31	$804.67
PBR 3	-$888.41	-$493.25	-$335.81	-$129.21	-$0.00	$138.15	$314.48	$407.51	$705.24
PBR 4	-$653.83	-$443.36	-$318.33	-$120.64	-$0.00	$139.25	$248.22	$282.06	$509.65
PBR 5	-$519.81	-$375.60	-$265.31	-$117.80	$0.00	$135.00	$233.21	$253.88	$284.50
PBR 6	-$305.42	-$295.68	-$278.61	-$23.81	$0.00	$76.86	$119.05	$162.40	$164.10
Ungrade	-$852.72	-$586.88	-$311.50	-$106.14	-$0.00	$131.48	$207.57	$278.07	$603.83
Overall	-$888.41	-$486.24	-$330.36	-$126.59	-$0.00	$136.87	$286.30	$396.63	$804.67

Table 23. Screenshot of 'Differences' summary table by PBR and $ per Kg HSCW

Differences kgs

PBR	Min (Overpaid)	1%	5%	Q1	Mean	Q3	95%	99%	Max (Underpaid)
PBR 2	-$0.65	-$0.65	-$0.65	-$0.33	$0.00	$0.30	$0.95	$1.45	$3.20
PBR 3	-$0.66	-$0.66	-$0.66	-$0.27	$0.00	$0.29	$0.94	$1.19	$3.19
PBR 4	-$0.98	-$0.68	-$0.68	-$0.43	$0.00	$0.42	$0.77	$0.97	$2.42
PBR 5	-$0.69	-$0.64	-$0.59	-$0.39	$0.00	$0.41	$0.65	$0.91	$1.11
PBR 6	-$1.07	-$1.03	-$0.92	$0.01	$0.00	$0.33	$0.49	$0.62	$0.68
Ungrade	-$1.32	-$0.93	-$0.88	-$0.42	$0.00	$0.43	$0.72	$1.05	$3.53
Overall	-$1.32	-$0.68	-$0.66	-$0.27	$0.00	$0.37	$0.88	$1.15	$3.53

'Producer Outcomes' Tab

This tab provided the capacity to look specifically at each individual or a collection of producers by selecting advice codes. The 'Producer results' window showed a violin plot that indicated the $ distribution of that producers' cattle population. There were two violins, one displaying the actual $ paid to the producer (premiums included) and the other a value based payment (PBR calculated prices and premiums added in afterwards). At this point all funds had been redistributed. On the violin plots, the middle horizontal line indicates the average $ paid per Head for that producer's cattle population. In the Fig. 40 example below, the standard payment indicated a purchase cost of $2,912.03 per/hd whereas the VBP produced a value of $2,613.97 per/hd, indicating that the processor overpaid $298.07 per/hd on average for these cattle.

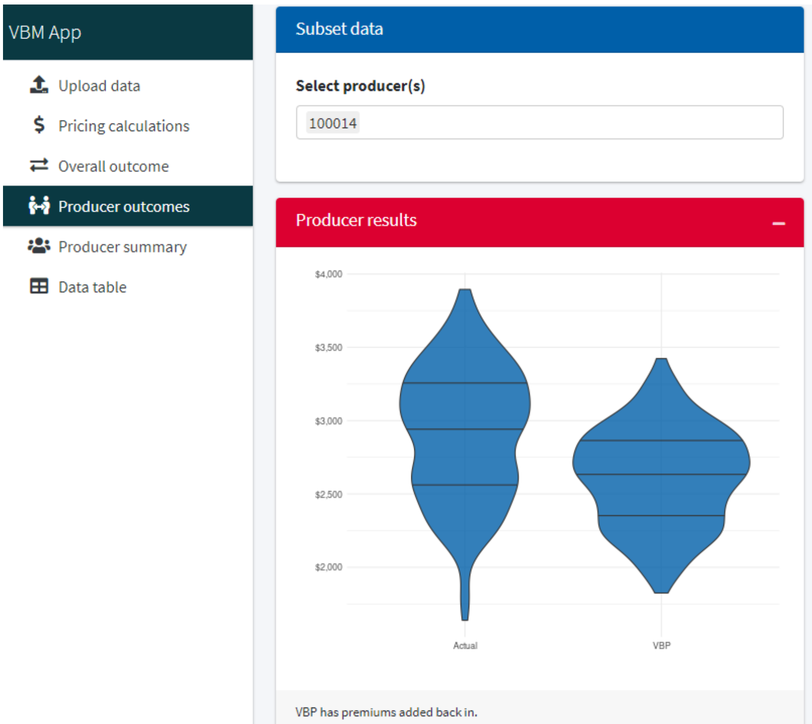


Figure 40. Screenshot of distribution violin plots for a selected producer displaying Actual vs VBP differences $ per/head from 'Producer outcomes' tab

The ‘Carcase Overview’ window displayed in Fig. 41 presents boxplots of the distribution of LM% for the selected producer/s (the upper boxplots) relative to the entire plant population (the lower boxplots within each PBR. As VBP values were calculated from LM Kg rather than HSCW higher or lower VBM returns can result from LM% relative to other mobs.

The bar charts under the comparative box plots displayed some of the key carcase attributes that may be of interest in assessing the range of each within the consignment.

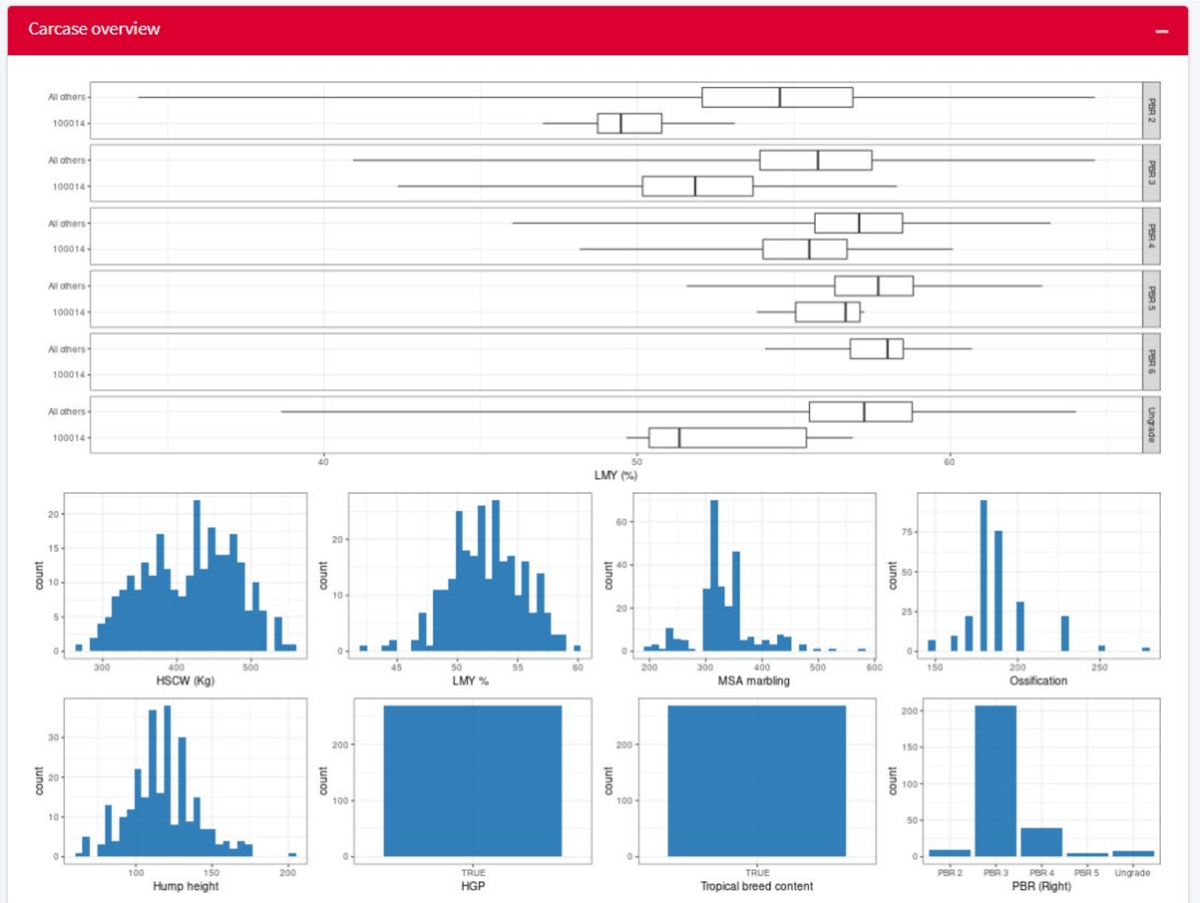


Figure 41. Screenshot of summary graphs for selected producer

The actual App screen output displayed the detail in Figs. 39 and 40 on a single page for convenience as shown in Fig. 42.

Figure 42. Screenshot of summary graphs for advice 100115 from the 'Producer outcomes' tab

The 'Carcass level data' window of this section provided individual carcase results from the selected producer. In the Table 24 example there are some cases where the processor overpaid (-$) and underpaid ($) for the carcass.

Table 24. Screenshot of 'Carcass level data' table from the 'Producer outcomes' tab

Carcass level data

Show 10 entries

Carcass ID	Advice	Carcass owner	Kill date	LMY %	LMY Kg	$/Kg HSCW raw paid	$/kg HSCW premium paid	$/kg HSCW avg	$/kg VBP	$/head HSCW avg	$/head VBP raw	$/head VBP with premiums	$/head originally paid	$/head difference	PBR right
8191265	100014	BEEN	2021-03-03	47%	232.153457248	$7.01	$0.00	$6.75	$12.23	$3,310.59	$2,838.98	$2,838.98	$3,435.75	-596.772995304073	PBR 3
8191266	100014	BEEN	2021-03-03	52%	220.6551348	$7.01	$0.00	$6.75	$12.23	$2,875.84	$2,698.37	$2,698.37	$2,984.55	-286.184612332802	PBR 3
8191267	100014	BEEN	2021-03-03	50%	257.053323648	$7.01	$0.00	$6.75	$12.23	$3,445.60	$3,143.47	$3,143.47	$3,575.86	-432.385491938939	PBR 3
8191268	100014	BEEN	2021-03-03	50%	223.026423648	$7.01	$0.00	$6.75	$12.23	$3,040.55	$2,727.36	$2,727.36	$3,155.51	-428.146403170781	PBR 3
8191355	100014	BEEN	2021-03-03	60%	161.128917072	$6.11	$0.00	$6.43	$11.32	$1,723.21	$1,823.91	$1,823.91	$1,637.63	186.282001487269	PBR 4
8197449	100014	BEEN	2021-03-03	58%	171.043800928	$6.11	$0.00	$6.43	$11.32	$1,879.98	$1,936.14	$1,936.14	$1,786.62	149.524343061501	PBR 4
8197398	100014	BEEN	2021-03-03	58%	171.313523072	$6.11	$0.00	$6.43	$11.32	$1,883.84	$1,939.20	$1,939.20	$1,790.28	148.917485008012	PBR 4
8197430	100014	BEEN	2021-03-03	58%	169.485378312	$6.11	$0.00	$6.43	$11.32	$1,864.56	$1,918.50	$1,918.50	$1,771.96	146.543650351815	PBR 4

'Producer Summary' Tab

This tab provided a summary of producer mobs and the overall paid $ differences. The 'Options' windows provided 4 different visual options for data display.

1. Total paid difference $/head by advice code (Fig. 43)
2. Average $/head paid by advice code (Fig. 44)

3. Total paid difference $/head by advice code, separated by PBR (Fig. 45)
4. Average $/head paid by advice code, separated by PBR (Fig. 46)

The size of the dots indicated the number of cattle in each mob. If the cursor was hovered over the dot information was displayed regarding the number of head, total $ difference and the producer advice number.

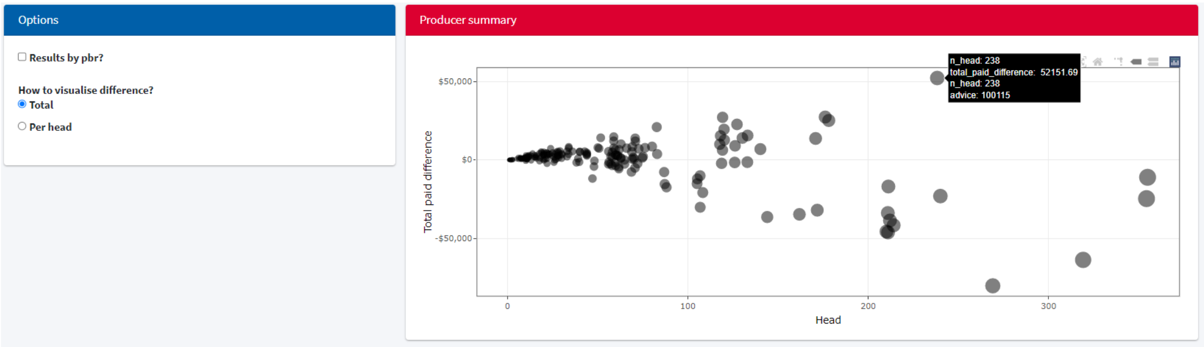


Figure 43. Screenshot of Producer Summary graph for the Total paid difference $ per/head by advice code

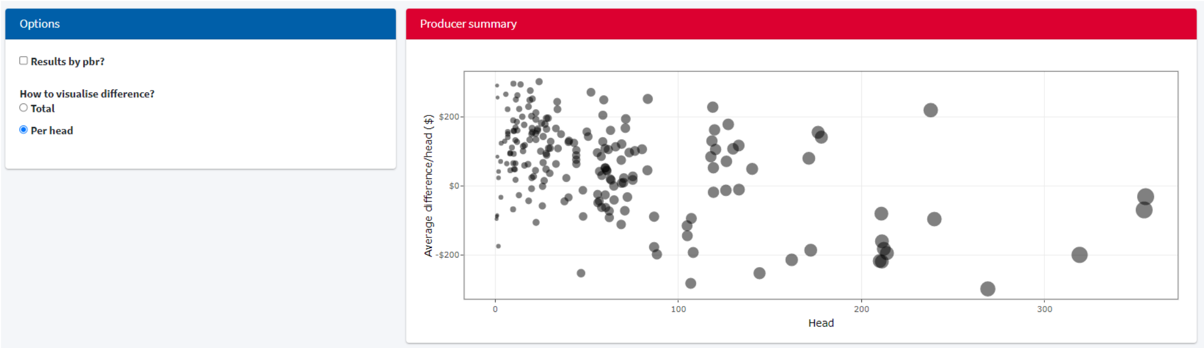


Figure 44. Screenshot of Producer Summary graph for the average $ per/head paid by advice code.

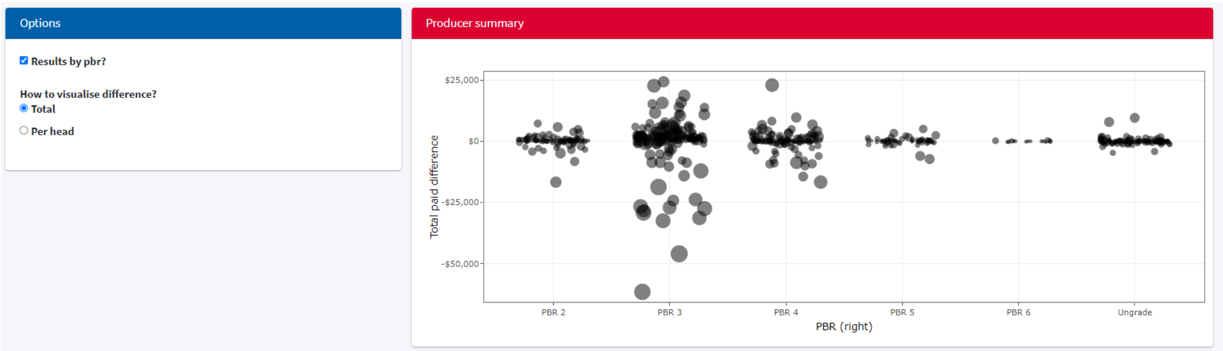


Figure 45. Screenshot of Producer Summary graph for the Total paid difference $ per/head by advice code, separated by PBR.

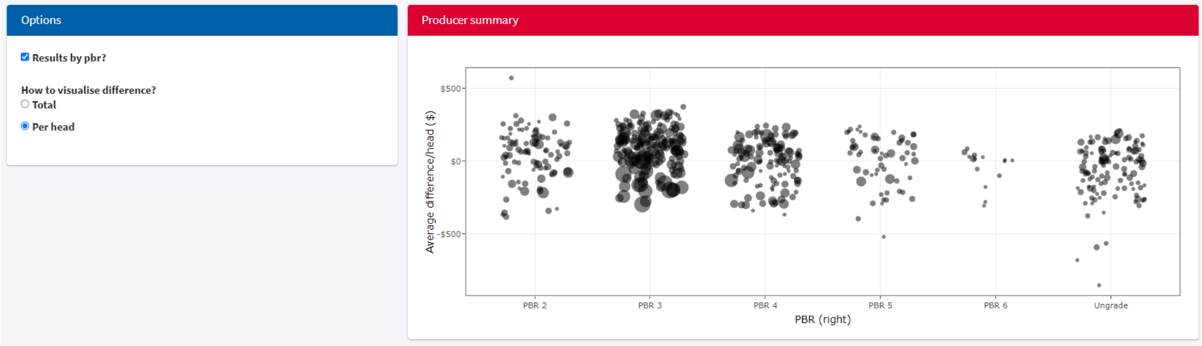


Figure 46. Screenshot of Producer Summary graph for the average $ per/head paid by advice code, separated by PBR.

The 'Producer summary data' window displayed in Table 25 summarised the Actual and VBP payment differences by advice code. In this example there are advices that if paid on VBP would have attracted premiums or penalties.

The software allows sorting on values in any column facilitating ranking of producer consignments or individual carcasses on any desired criteria and provided a basis for analysis of the impact of a VBM system across individual cattle consignments, the cheque book test likely to deter or excite initial producer response.

Table 25. Screenshot of 'Producer summary data' table detailing the paid $ differences for each advice code.

Producer summary data

Show 10 entries

Search:

Advice	Head	LMY (%)	Total original paid	Total VBP paid	Total paid difference	Original per head	VBP per head	Difference per head
100303	355	56%	$826,449.63	$815,363.50	-$11,086.13	$2,328.03	$2,296.80	-$31.23
100365	354	57%	$770,950.61	$746,291.15	-$24,659.46	$2,177.83	$2,108.17	-$69.66
100120	319	53%	$766,497.73	$702,825.56	-$63,672.17	$2,402.81	$2,203.21	-$199.60
100014	269	52%	$783,337.37	$703,156.63	-$80,180.74	$2,912.03	$2,613.97	-$298.07
100122	240	57%	$585,557.23	$562,507.99	-$23,049.24	$2,439.82	$2,343.78	-$96.04
100115	238	57%	$445,235.84	$497,387.53	$52,151.69	$1,870.74	$2,089.86	$219.12
100029	214	55%	$566,038.38	$524,407.33	-$41,631.05	$2,645.04	$2,450.50	-$194.54
100115	238	57%	$445,235.84	$497,387.53	$52,151.69	$1,870.74	$2,089.86	$219.12
100118	176	56%	$357,723.79	$385,008.83	$27,285.04	$2,032.52	$2,187.55	$155.03
100116	119	57%	$229,226.06	$256,334.27	$27,108.21	$1,926.27	$2,154.07	$227.80
100145	178	56%	$375,001.58	$400,094.17	$25,092.59	$2,106.75	$2,247.72	$140.97
101397	127	60%	$195,926.44	$218,526.71	$22,600.27	$1,542.73	$1,720.68	$177.95

4.1.5.2. VBM and VBP analysis results

Monthly files for each plant were loaded and analysed through the updated Birkenwood maximiser software to examine the spread of actual livestock payments relative to a redistribution of the same pooled amount on a VBM basis. These comparisons were calculated across the monthly plant cattle populations and within and between consignment mobs.

Within the tables the variation across quantiles within each PBR row reflects only yield as a common $/kg LM rate is applied to all animals in that PBR. The consumer satisfaction and value difference are related to the difference between PBR rows which as discussed include all rather than just VBM marketed carcase portions. The overall row provides a combined PBR view where yield and quality are shown across the entire mix.

The analysis was done on the basis of total livestock price paid; a very imprecise measure of the actual revenue generated even at the macro level. This in fact tended to underplay the scale of price premiums gained by the marketing team adopting the principle of VBM with the proportion of cuts marketed under this framework beginning at a small but important base with an objective to expand both the proportion of the carcase sold under EQ based brands and the premium applied to alternative brand levels.

The full VBM impact is a combination of effectively delivering a consumer focussed VBM sales structure to generate maximum revenue and transmitting these VBM signals back though a VBP livestock purchasing system that results in improved livestock potential. A virtuous circle of transparent data sharing and pricing is completed by receiving higher margin raw material. The concept is represented in Fig. 47 which depicts a move “to the right” in supply value distribution. As shown the mean value of each kg supplied is not only increased but the distribution range is also tightened. This would deliver appreciable processing benefits in more uniform and higher value livestock generating greater revenue through improved yield and higher priced branded sales within the existing unit based cost structure.

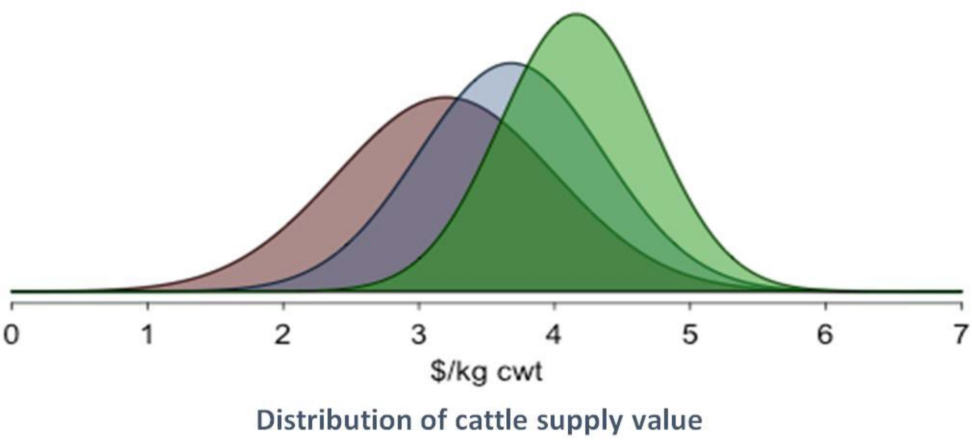


Figure 47. Conceptual transition of carcases value change through improved yield and eating quality influenced by transparent yield and EQ based payment.

The producer benefit derives from utilising essentially the same resources to turn off higher value more profitable animals enabled and incentivised by clearly communicated actionable information and direct true value linked price incentives. This envisages the conceptual progressive improvement depicted in Fig. 48 with livestock payments becoming more aligned with the VBM derived market signals that reflect final consumer value.

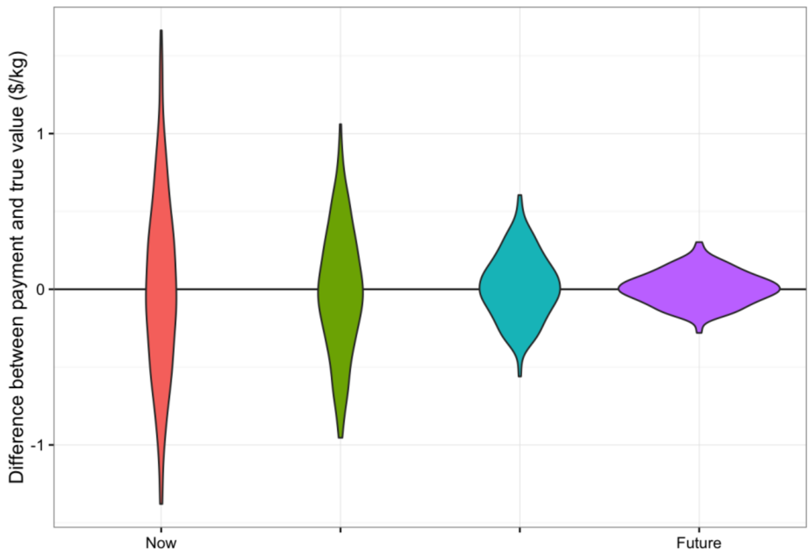


Figure 48. Conceptual transition of payment relationship to actual value over time with VBM

4.2. Focus Area 2 – Re-branding according to Eating Quality

4.2.1. Preliminary evaluation

From the outset the overriding premise of the project related to developing and implementing an extremely strong and single minded strategy related to ultimate consumer value.

"OVER-RIDING PREMISE"

All the conclusions reached are built on a single premise: That all industry revenue is derived from the ultimate consumer whose value judgement and purchasing behaviour is directly related to the meal experience delivered at the price paid. If this premise is rejected, for all or specific types of products or market, then the conclusions should also be rejected for those products or markets.

Peer reviewed science has established that the MSA prediction model is effective at predicting consumer response across principal muscle and cooking method combinations and able to adjust for variations in cattle, processing, and ageing post slaughter.

This provides the ability and opportunity to directly relate product offers and descriptions to consumer satisfaction and value".

Following agreement on the core principle the initial project focus was on establishing base line data to enable comparison of suggested more sophisticated MSA based application and actual results over time. Much of this work including explanation of the original MSA Boning Group system and its limitations is presented in the methodology discussion within section 3.2.2.

The management system provided summary data on a weekly plant basis as shown in Fig. 49.

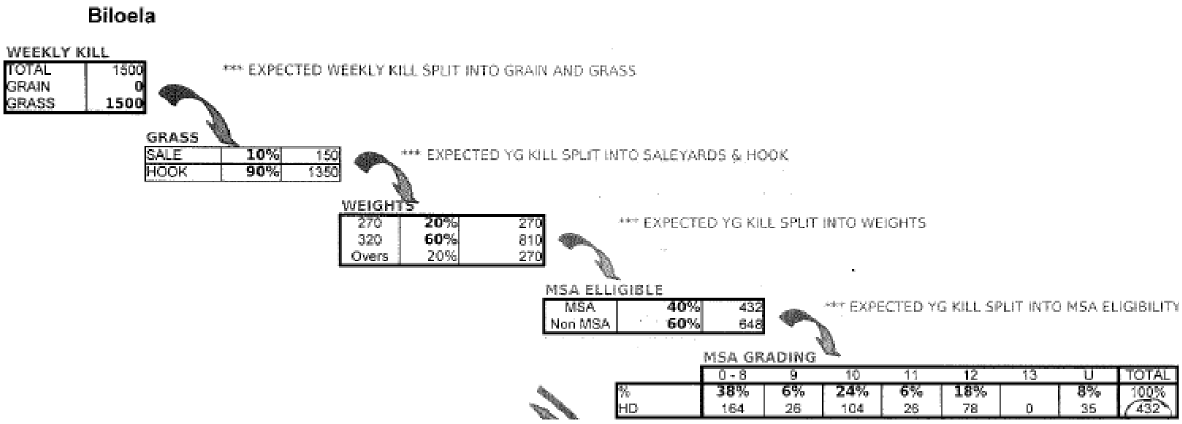


Figure 49. Example of kill breakdown.

As shown, cattle supply data and projections followed a format of grass and grain supply within dentition and carcase weight categories extended to MSA eligibility within MSA Boning Group categories. Baseline work of significance to later program development included detailed evaluation of dentition and associated ciphers in relation to eating quality.

The observed lack of relationship between dentition and consumer observed MQ4 reported from MSA research was further tested within data by plant and over 2012 and 2013 production years. It was confirmed that data exhibited a similar trend with MQ4 being widely distributed across dentition categories within grass and grain fed and sex based groups. The same lack of relationship extended to individual cut estimates. In contrast, as illustrated in section 3.2.3., increased ossification was associated with declining MQ4. Dentition and ossification were at best poorly related leading to the inevitable conclusion that ***dentition based carcase sorting and cut harvesting achieved no useful consumer function***, despite being the basis of AUS-MEAT language and traditional Australian carcase description and ciphers.

Fig. 50 illustrates the issue with very large (MSA database sourced) cattle numbers within male and female and grass and grain fed categories. The MSA Index, a yield weighted average of individual cut MQ4 values, is graphed against dentition within sex and feed type with the extreme overlap of MSA Index obvious, the central 50% of values (the thick box within each box plot) overlapping in virtually every category.

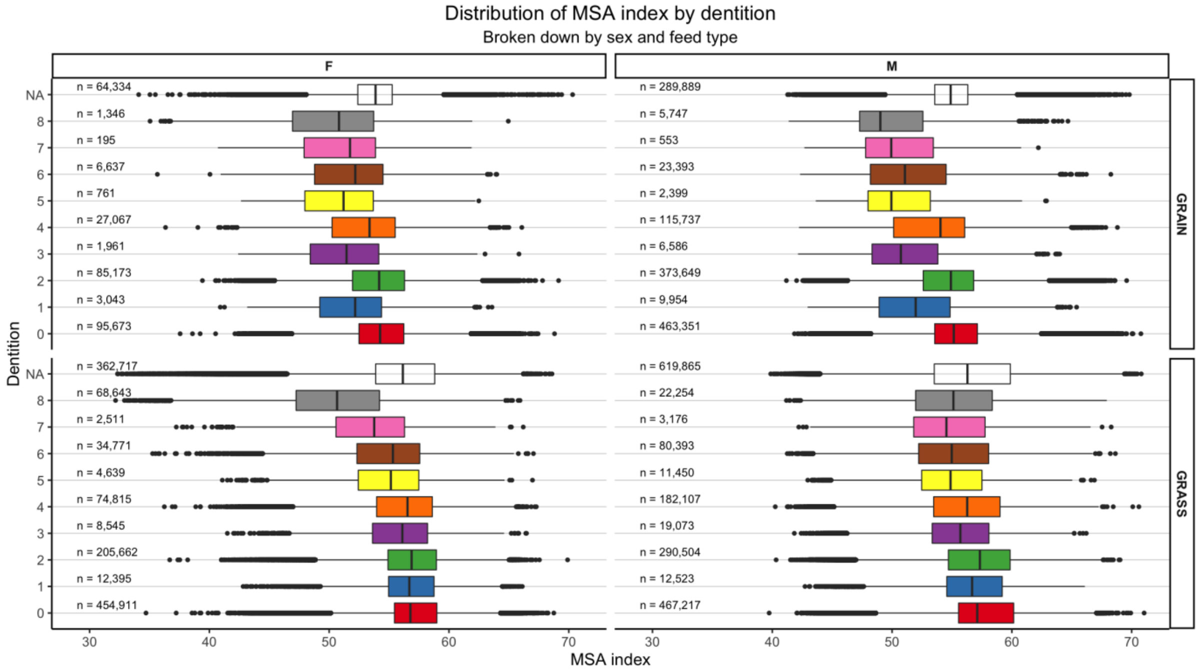


Figure 50. Distribution of MSA Index within Feed Type, Sex and Dentition (MSA data, 2018)

These results were communicated strongly to management and supported the recommendation to move away from dentition based sorting in favour of MQ4 based categories that directly reflected consumer satisfaction and hence ultimate value. This recommendation offered the prospect of reduced complexity from maintaining MSA based criteria within dentition cipher but also created issues in regard to export market or customer dentition based specifications. In the base situation this was complicated by the mix of premium cuts being MSA graded, and others sold on cipher without MSA labelling. If bodies were to be sorted on the brand based MQ4 to collect branded cuts then others would revert to the lowest cipher in the run which could, for example, downgrade from YP to S or similar or fall out of the 4 tooth criteria for EU eligibility.

These difficulties were acknowledged and considered in conjunction with other sorting decisions. Ironically the addition of MQ4 based branding to more cuts reduced rather than increased complexity related to brand (PBR) based sorting. A major source of product complexity related to cut codes and labelling with rump, for example having 94 active label codes due to the combinations of dentition based ciphers, weight ranges and cutting specifications. The later introduction of the EQG cipher provided a valuable solution to the problem for most markets with an early adopter.

Tropical Breed Content (TBC%) was a major input into the then current SP2009 MSA model calculation, with higher TBC% reducing the MQ4 scores for most cuts, striploin being affected to the greatest degree. Two alternative forms of model input were allowed: the actual TBC% advised on the MSA Vendor Declaration or an alternative of calculating TBC% from measurement of hump height in conjunction with carcass weight.

Where the Vendor Declaration TBC% was used the % advised was assumed to be correct but cross-checked by relating the measured hump height to carcass weight during the grading process. If the hump height exceeded an expected range for the carcass weight the TBC% was adjusted up. If it was within range the declared TBC% was used.

If the hump height alternative (entered as 110 TBC) was elected the TBC% was estimated from the expected TBC% for an animal of equivalent carcass weight and hump height. As this estimate was based on conservative mean values it generally returned a higher TBC% estimate and lower MQ4 other than at the extremes, as shown in Table 26, which displays the relative estimates for an example range of carcass weight and hump height combinations.

Table 26. MSA model estimates of TBC% from hump height relative to declared maximum %

		Calculated BI%	
HSCW	Hump	From Hump	From BI%
200	50	0	0
200	60	0	0
200	100	80	40
200	150	100	90
200	160	100	100
200	200	100	100
250	50	0	0
250	65	0	0
250	100	70	35
250	150	100	85
250	165	100	100
250	200	100	100
300	50	0	0
300	70	0	0
300	100	60	30
300	150	100	80
300	170	100	100
300	200	100	100
350	50	0	0
350	75	0	0
350	100	50	25
350	150	100	75
350	175	100	100
350	200	100	100

From Table 26 it is seen that at the extremes of 0% and 100% the Vendor Declaration and hump height estimates agreed. Outside this range however the hump height estimated TBC% was often double.

Given that standard company practice had been to use hump height for all cattle other than 0% TBC%, analysis was conducted to determine the relative result of using Vendor Declaration values in the belief that more favourable grading results might be obtained. To test this assumption TBC% data from all MSA eligible cattle assessed for an 8 week period was analysed. Over this period a total of 12,265 head, 29.1% of eligible stock, had been entered as 0% whereas 70.9% (29,931 head) had TBC% estimated by hump height. The hump height and carcass weights were then used to respectively calculate the TBC% from hump height and carcass weight for all cattle and the comparative maximum TBC% allowed via Vendor Declaration.

The overall TBC% result for 29,931 head was as follows:

	Est. By Hump	Est. By Vend. Dec
Average	46%	26%
Minimum	0%	0%
First quartile	5%	2%
Second quartile (median)	43%	21%
Third quartile	83%	42%
Maximum	100%	100%

From this analysis it was established that a substantial benefit would result from substituting Vendor Declaration values for the hump height option, with the average and median values for all cattle indicating a potential 20% reduction in TBC% estimates and the third quartile of the population 40%. As expected, the 0% and 100% extremes were found to be equal.

This conclusion and supporting analysis were discussed with management and via PowerPoint presentation. ***The proposal was implemented providing improved MSA product volume and grading outcomes, benefiting the entire supply chain from supplier to customer through increased accuracy and reduced product variation***.

Further analysis was also conducted on the impact that might be expected if tenderstretch carcase suspension was adopted. While MQ4 increases were considerable for some key high value cuts it was decided that restricted chiller space made it impractical at the time. A further consideration was that for the large proportion of exported product the tenderstretch benefit became less as longer voyage related ageing time reduced the gap between Achilles and Tenderstretch suspension. At a later time some alternative hind leg trussing options that reduced space while retaining aitch bone suspension were observed in Europe and passed on for consideration.

To assist in understanding the fundamental linkages between consumer satisfaction, basic meat science, and the impact of on-farm and abattoir actions an applied meat science course was requested by management. A course, drawing on the MSA meat science course, but tailored to the project within and associated marketing strategy, was arranged and presented by Dr John Thompson and Rod Polkinghorne over two and a half days. The course was attended by a very enthusiastic group from production and marketing departments with excellent interactive participation from all parties. Further seminars using PowerPoint presentations were conducted with broader groups within and supported a number of written reports detailing the initial data analysis and principles recommended as a base to the transition to a very consumer centric focus from marketing to cattle procurement; a fully integrated supply chain model with all segments aligned with ultimate consumer value.

4.2.2. Transition to an MQ4 branding strategy.

The initial analysis was conducted utilising standard MSA grade cut offs or 46 for 3*, 64 for 4* and 77 for 5*. These analyses indicated that a very high proportion of cuts from the northern plants in particular fell within the 3* category reducing the opportunity for more differentiated branding.

Subsequently an alternative of dividing the 3* grade at 55 MQ4 was instituted and modelled. This provided more effective segregation and maintained a 7 MQ4 point segregation able to be recognised by typical consumers.

Adoption of standard MSA grade settings however produced two results worthy of discussion:

1. If utilised many brand settings would most likely be identical to many other groups, reducing the degree of difference to competitor brands.
2. The volume of product would be radically different by cut due to tenderloin, for example, mostly being 4* and 5* and topside, for example, mainly 3* or ungraded.

A number of workshops were conducted with marketing and sales groups to agree a preferred strategy. The outcome was a decision that branding should be applied to assign a relatively common proportion of each cut to common brand categories. It was agreed that grass and grain fed brands should have common settings to enable packing under common codes where feed type wasn't specified. Implementing this strategy meant that "Platinum" brand would represent the, for example, best 25% of product within each cut with the individual cut settings selected to achieve close to 25% capture. An appealing impact of this decision was that brands could be significantly different to competitors providing clear points of difference and potentially more consistent eating quality differentiation due to a reduced MQ4 range within brand categories.

A philosophic disadvantage was that the approach reinforced a cut based description basis rather than the Birkenwood advocated transition to a meal outcome categorisation. This approach was considered too challenging at the time – closer to the bleeding edge rather than cutting edge – and rightly requiring considerable investment in customer education to implement successfully. It was also agreed that alternative descriptions such as 4* or Platinum stir fry meat could be introduced to enable mixing of cuts with equivalent cooked outcome. This was advocated in particular for value adding raw material and commercial food service customers where a consistent raw material would translate to improved final ready meal performance with potentially reduced input cost. It was agreed that major retail customers were not amenable to any short term transition.

Following the initial analysis a major data modelling exercise was undertaken utilising two years of production data. These data were divided into monthly files within grass and grain fed supply from each plant resulting in 60 base files across the group (All plants except Tamworth).

The files were loaded and extensively analysed using the Birkenwood software to produce individual MQ4 values for 39 MSA muscles from over 1,500,000 bodies. As discussed in the methodology section MQ4 distributions for each cut were produced and progressive cut counts calculated from 1 to 100 MQ4 to indicate the % that fell within any nominated MQ4 range. These indicative cut-off settings were implemented in the software with bodies allocated to categories after checking the minimum MQ4 value for every cut in the prospective PBR. Offsets for alternative cooking methods and ageing potential were also considered and applied to each cut to improve branded capture where considered appropriate (the cooking method was realistic).

Given that the first cut to fail resulted in a carcase moving to a lower PBR category many other, in fact most, cuts in the downgraded carcase were actually at or above their individual minimum setting. A deep study of these relationships informed the lack of consistent MQ4 relationships between cuts, confirmed and quantified by assembly and testing of different categories including HGP treated or HGPFRE and of 0% TBC relative to high TBC%.

A priority was established for the most valuable cuts and the relative cut-off scores for those less valuable reduced slightly to reduce the chance of a brisket triggering the loss of loin cuts for example. After each test run of a given file the lowest, average, and highest scores for every cut type were examined to determine how close they were to their cut-off value after all failed bodies had been rejected. Where the lowest scoring body had an MQ4 score well above the minimum this setting was typically adjusted up and where on the minimum the score distributions examined to determine if that cut was triggering failures. This iterative process was followed extensively until a balanced outcome with close to maximum capture of most desired cuts was achieved with minimal loss of others.

Recommended initial brand related PBR settings were derived from the process and tested against daily and monthly production from current production.

Data from the initial 2 years were also used to compare MSA Boning Group based capture, the base for the MSA developed PBR then in place, with the developed independent MQ4 based settings and extrapolated to projected cut weights and revenue under alternative scenarios.

The modelling indicated that the brand strategy offered considerable potential with attention moving to more detailed evaluation of the physical application within each plant and across the customer base.

Individual daily production modelling was conducted in conjunction with experienced production managers to compare actual daily carcase sorting with the theoretical approach. This raised a number of practical issues including the impact of different categories such as Organic or EU which required segregation and consideration of HGP and HGPFRE or Angus categories related to trimmings capture for specialised markets.

In contrast the new MQ4 refined PBR specifications provided a strong base for brand segregation due to the extensive quality differentiation for most cuts

For some cuts common MQ4 values were adopted for adjoining PBR but at different ageing times providing a common consumer meal outcome after ageing. In concept the longer aged product could be prioritised for export shipment. Due to the larger number of MSA branded cuts, reduced product codes and adoption of the EQG cipher the proposed program offered reduced operational complexity.

4.2.3. Advanced application in conjunction with the new MSA V2.0 model

The planned introduction of a new and radically changed MSA prediction model created both challenge and opportunity to review the recently introduced comprehensive branded activity and to examine and adapt to the revised and additional calculation outcomes from MSA V2.0. The model detail and supporting research data was well known to Birkenwood due to direct involvement and supported by further extensive international work utilising MSA research and sensory test protocols. Analysis to support the transition was conducted over an intense 7 month period involving extensive collaborative work with the marketing, production, and analyst teams.

To facilitate these analyses and also provide detailed MQ4 level data for analysts an extensive redevelopment of the Birkenwood software was commissioned with EC&V consulting. This included the addition of the V2.0 model calculation to enable direct model comparisons and more sophisticated procedures to enable brand based provenance and market eligibility criteria to be included in analysis in addition to the MQ4 base. A significant change was automated daily loading of all MSA eligible cattle rather than the prior need to obtain data from IT and then create and assemble files for loading. This approach was far more efficient and, with a significant improvement in computational speed from software enhancement and transfer to the AWS cloud, enabled rapid analysis of very large data sets. Procedures that had taken an hour to run and required further manual work to adjust for non MQ4 related criteria were replaced by run times of a few minutes. An additional service was provided to allow IT to download individual cut MQ4 values for all cuts from all bodies with the capability to nominate either or both MSA models and any combination of cook methods, cuts, and ageing days.

A thorough review of branding objectives was conducted in conjunction with the marketing team and included more detailed application and market nuances than in prior work. This was facilitated by experience with the recent expansion to the 5 PBR structure and transition to including the majority of cuts within an EQG based brand structure. It was agreed that the established principle of branding directly reflecting consumer value remained a non-negotiable core requirement. Prior activity directly defined consumer value as consistent eating quality defined by MQ4 based quality bands as depicted in Fig. 51, a slide from one of many PowerPoints based marketing presentations. This underlying assumption was consistent with willingness to pay (WTP) research data collected using MSA protocols in 8 countries that indicated, on the basis of cooked sample sensory evaluation, average consumers valued “good everyday quality”/3* product double that of unsatisfactory quality with, typically a 50% premium for “better than everyday”/4* and a 100% increase over 3* for a “premium” eating experience.

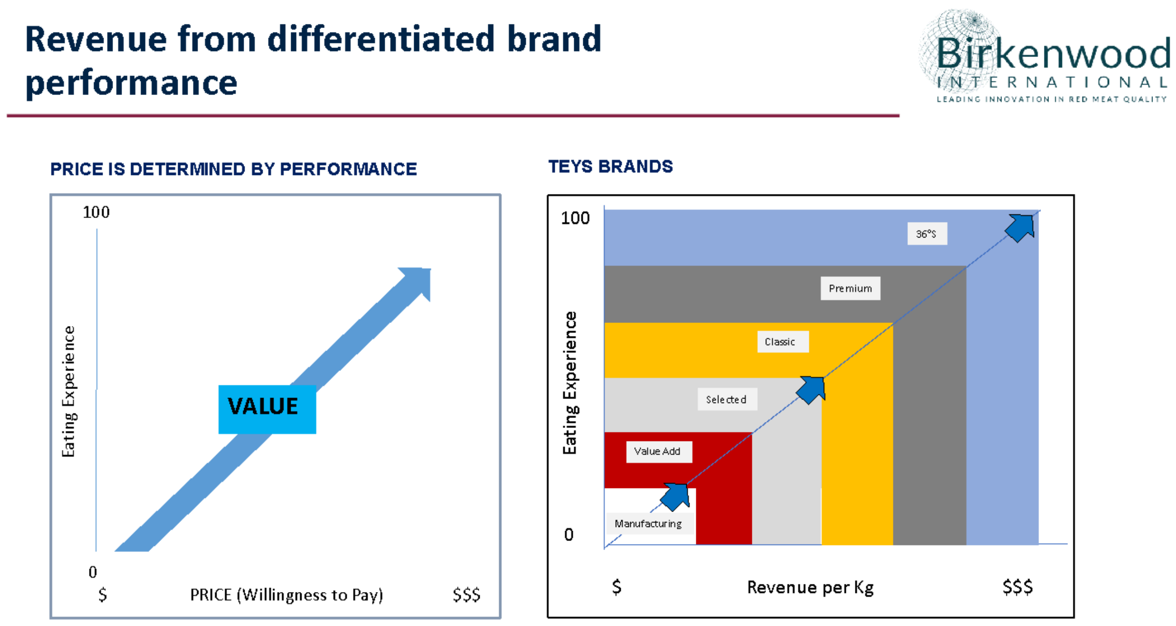


Figure 51. Conceptual relationship of consumer Willingness to Pay to Brands

The discussion was extended to include the value of provenance attributes or claims within the brands, with these often being the public face, and customer association with the meal outcome to be delivered. Clearly provenance and actual performance needed to be complimentary for highly successful branding but there were trade-offs in production complexity, with potential to multiply the number of production runs from a base of 3 MQ4 based sorts per plant to multiple sub-categories based on provenance criteria, often unrelated to the eating experience.

Issues of note included dentition limits of 0 to 4 teeth included in many specifications, the use of Angus within some brand specifications and the inclusion of an arbitrary AUS-MEAT marbling score 2 in the Riverine Premium brand in addition to MQ4 specification that already reflected the impact of marbling. Further discussion related to the need, or otherwise, to include feed type definitions or an HGPFRE or “never ever” antibiotic or grain feeding overlay to specific brands. It was noted that while the Angus brand was sold as a premium brand it was not supported by the Premium PBR specification raising the question of either a change to the higher PBR, introduction of two quality levels or a change to the quality connotation. Considerable discussion addressed the inherent trade-off between operational simplicity and non MQ4 based provenance criteria.

The balance between continuity, and associated customer familiarity with the existing brand offer, and change to achieve either simpler production or more consistent cooked meal experiences was a key discussion topic. Interaction with major retail customer specifications and supply of product to complement a customer supply base, particularly for major promotions, was a further consideration with supply made simpler if cut settings were either equal or superior to customer criteria.

The ability to substitute alternative cuts or sub primals of equivalent performance was also raised and agreed to be an important issue that could assist both and customers in times of tight supply or price pressure. It was agreed that the sales team required additional technical knowledge and confidence to progress this aspect. The sales team needed to become a trusted source of customer advice and be valued as a partner in delivering a desired consumer experience within often tight price constraints. This capacity was seen as needing to include the AFS team where it was relevant to both raw material purchasing and in delivering cost effective final product solutions, including the potential to substitute value added products.

Concurrent with regular marketing workshops a comprehensive analysis of the most recent 24 months data was conducted using existing PBR settings across the then current MSA SP 2009 model and the new V2.0 still being finalised at the time. Initial analysis utilised only the muscle and cooking methods in the SP2009 version to provide a direct comparison with monthly production at each plant compared to identify overall model induced differences in number of head by brand and an indication of how these might relate to diverse cattle populations.

Many other differences were observed across cuts, ageing rates, and cooking methods using a process of sequential testing. For this process Birkenwood software output that indicated the lowest MQ4 score for each cut within a PBR, together with means, maximum and counts by MQ4 value was utilised. Limiting cuts, being those where the lowest MQ4 coincided with the cut-off value, were identified and the cut-off score increased before re-running with the next most limiting adjusted, and so on, until all SP2009 cuts were close to their individual cut-offs by which stage the numbers harvested were approaching parity for the V2.0 model.

When these amended settings were run across northern and southern plants it was noted that the V2.0 counts tended to be better for the higher *bos-indicus*% and HGP populations. This in part resulted from the new hump based model calculation replacing the previous conversion to TBC%, but also to the hump height being increased with HGP treatment. In effect the direct application of hump height in the MQ4 calculation transferred some of the HGP effect to the hump input, reducing the apparent effect of a straight HGP/HGPFRE input. Further study was made with groups of varying TBC% and with and without HGP in order to gain further insight.

Once the nuances driving the model differences were better understood analysis was concentrated on the new model version with the cuts expanded to include many not in the older version. Relative cook score differences were examined within each muscle together with new alternatives, and in some cases the reference cook method recommended for branding changed to achieve a better consumer outcome and associated value. The new version also provided the option to increase ageing from 35 to 50 days for all cuts bar tenderloin and included some changes, the most notable being a substantial ageing decrease on many slow cooked muscles. Again, ageing days were amended where beneficial and commercially practical.

This process was followed by detailed consideration of provenance based brand criteria such as Angus and prospective cut-off scores that could accommodate the mix of MQ4 and provenance desired. Extensive workshopping was conducted with the marketing team and data analysts to examine prospective harvest numbers at alternative settings, volume, and balance of cuts within brands and monthly volumes across the 5 sites.

The 5 level PBR basis was retained but actual settings extensively re-worked to optimise harvesting under the V2.0 model. Considerable effort was made to simplify cut codes and provide for common codes across PBR where there was insufficient difference to justify sorting. The PBR 5 (Value Add) settings were made identical to PBR 4 (Selected) to simplify boning room operations. Both PBR could be boned to common specifications with the only operational adjustment packing a reduced number of cuts under an MSA brand umbrella within PBR 5.

A consequence of adopting the new PBR settings was that “cuts that failed” or were excluded from a PBR were also in essence sorted into more uniform MQ4 groupings providing a consistent raw material base for value adding. This potential benefit was discussed with value add facility management and with the marketing team who might use the information to assist in third party sales to value adding/manufacturing customers.

In conjunction with the analysis and marketing teams extensive reworking and testing of alternative settings within individual brands was conducted to determine likely cut volumes based on the previous 12 months data. These results influenced further, mostly minor, setting adjustments and also additional analysis for specific issues.

These and many related evaluations consolidated an agreed strategy where each plant would predominantly utilise only 3 PBR categories thereby reducing sort complexity and delivering more efficient production. The use of the EQG cipher was also to be adopted wherever possible due it further simplifying plant operations and labelling. In effect only 3 primary boning runs were required for MSA product within market access requirements.

4.2.3.1. Marketing support and capacity building

The transition from an essentially large scale global commodity marketing structure selling product described principally by AUS-MEAT cipher and HAM code, partially overlaid with a basic MSA grade, and branding structure, to marketing originating from a consumer meal outcome and working back to consistent simple solutions delivered through strong brands, required both cultural and operational change. This aspirational direction had been initiated by the leadership team and progressed through intensive interaction by Birkenwood with operational and marketing teams over several years.

The fundamental change was particularly challenging for the sales team which needed to reskill and move from a well-established and comfortable product base responding to specific orders, such as "quote 100 tonne of PR knuckles for September delivery", to being trusted advisors providing recommendations that could reliably deliver an end user, in effect end consumer, the best value meal solution. This required more detailed knowledge of how the product was to be utilised and the applicable quality/price value relationship. It also demanded expert product knowledge beyond the HAM specification. More detailed knowledge of MSA application became a "core competence" requirement that had not been critical in the past.

The sales offer was to become "the carton lid" which provided a category or brand backed promise of consistent eating quality and related provenance. The business bore responsibility, and provided the expertise, to match this and the selection of cuts/muscles within the carton, to clear consumer outcomes. The customer was relieved of the responsibility of attempting to obtain an outcome by extensive specification of cut and cipher. This was designed to deliver a genuine "win-win" outcome where the customer required less specialised meat knowledge but received more consistent product outcomes, creating higher value and a commensurate revenue opportunity for the business.

Given that the sales force were the point of contact with customers they also bore the responsibility of "selling the system" and overcoming resistance from some customers who had well established buying habits and could view change as uncomfortable or suspect it was being made for rather than mutual benefit. It was recognised by Marketing senior staff that extensive training and education was required to empower the sale team and ensure they had the required background understanding to confidently sell the new system.

To assist in this process many workshops were held over the development period to both discuss progress and workshop alternative scenarios together with building knowledge of the MSA base and its sophisticated application within the branding program relative to competitors. The change to the MSA V2.0 model and associated additional cuts and reworking of all cut relationships with extensive brand revision required further knowledge transfer. To assist in this a comprehensive Eating Quality Based Brands Handbook, Fig. 52, was developed as a sales resource.

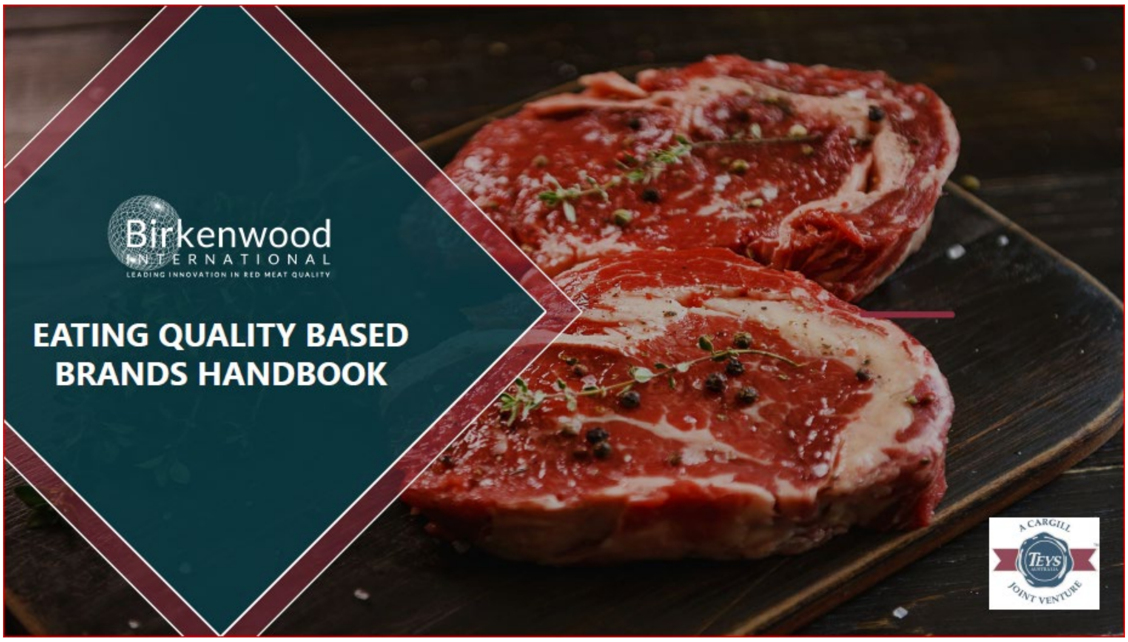


Figure 52. Header page of the Eating Quality Based Brand Handbook

The handbook provided an overview of the MSA system and its consumer evaluation base together with fundamental difference to international grading systems such as USDA and how this knowledge had been utilised in establishing unique brands that differed to "MSA" as sold by competitors.

The handbook then provided summary eating quality based rankings of cut by PBR (underpinning the 36˚South, Premium, Classic and Selected categories) within each of the major cooking styles to provide a sales guide as to which category x cut solutions could offer equivalent consumer results, within premium, mid and entry levels.

4.3. Focus Area 3 - Value adding to enhance eating quality and customer value.

At project commencement the processed meat business management had extensive practical value adding knowledge including practical experience in smallgoods operations and in producing a range of fresh pre-pack retail products, with a wide range of mechanically tumbled, injected, or marinated and cooked products.

While the processes were well known and conducted the outcomes relied on industry knowledge which had not been reliably quantified. Allied concerns related to effective raw material specification and the degree to which this might, or might not, impact the final product. Early decisions were made in conjunction with management to establish consistent measurement benchmarks by utilising MSA consumer testing protocols. This required experimental rigor and replication to ensure scientifically sound conclusions could be made, with the important additional practical impact that results related directly to consumer response and potential value in the market.

Results for the major study areas described in the methodology section follow:

4.3.1. Enhancement study at a processed meat facility

This study evaluated alternative enhancement treatments utilising traditional tripolyphosphate, a kiwi fruit extract (with and without additional needle tenderising), a ficin extract (with and without additional needle tenderising) compared to untreated controls across striploin, rump, and oyster blade primals. These cuts were selected from carcasses that represented a range of MSA eating quality within grass and grain fed cattle to enable treatment effects to be considered in relation to the initial raw material.

Table 28 presents the raw and treated weights for each treatment. While the raw weights were very similar there were significant differences between the mean percentage weight added between treatments (P<0.001). All treatment pairwise mean differences were significant (P<0.05) other than K+T – F+T and K+T – F10, as illustrated by Fig. 52. The phosphate (P10) treatment had the greatest mean % increase followed by kiwifruit (K10) with the tenderised treatment the least. While it was assumed that the mean % weight added related to moisture binding, and possible losses through the needle tenderisation process, a batch injection difference cannot be ruled out.

Table 28. Mean raw and processed weight (Kg), mean weight added (Kg) and mean percent weight added by treatment.

	Phosphate 10%	Kiwi 10%	Kiwi & Tenderised	Ficin 10%	Ficin & Tenderised	Sig	p-value
Raw wt	0.777	0.778	0.768	0.787	0.786	NS	0.907
Processed wt	0.928	0.891	0.845	0.882	0.855	S	0.011
Wt added	0.151	0.113	0.077	0.095	0.07	S	<0.001
%Wt added	19.0%	14.7%	10.5%	11.9%	8.8%	S	<0.001
Min	1.9%	-0.3%	-27.2%	0.0%	-15.0%		
Q1	12.0%	9.8%	7.3%	9.8%	7.0%		
Med	14.8%	14.1%	9.2%	11.9%	8.8%		
Q3	18.6%	16.8%	11.3%	14.3%	10.4%		
Max	79.0%	83.4%	87.9%	35.9%	18.4%		

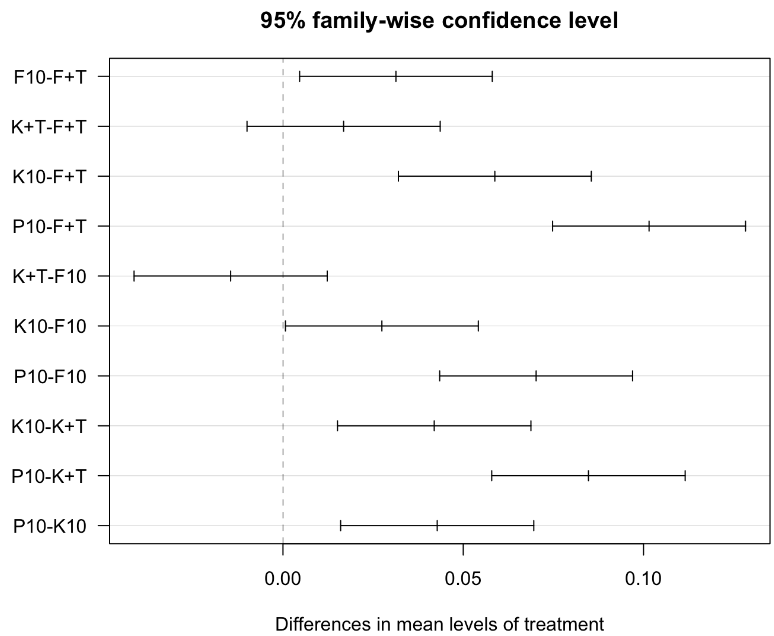


Figure 53. 95% family-wise confidence interval between pairwise treatment mean differences.

There was a reasonably consistent percent weight across treatments within each muscle. However, within the rump muscles, the P10 treatment was higher on average with a larger variability than the other treatment methods. Predicted means and confidence intervals are displayed in Fig.54.

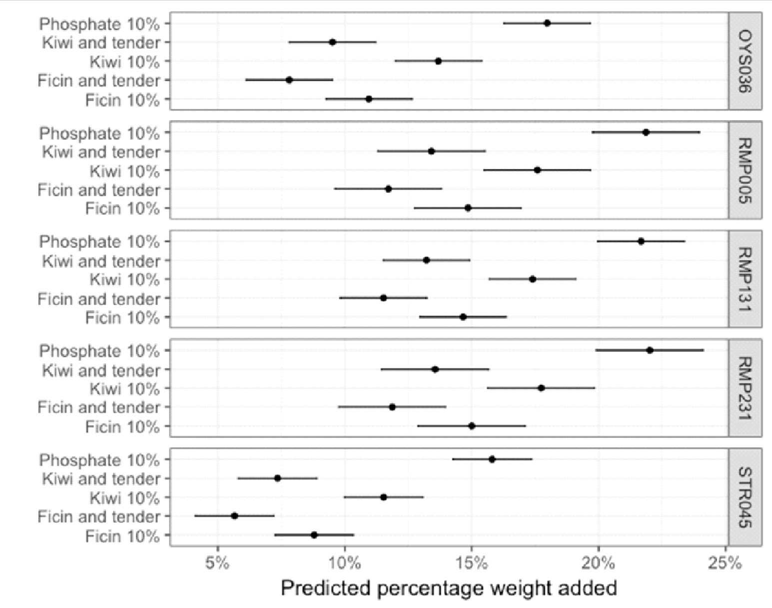


Figure 54. Predicted means and 95% confidence intervals for weight added by treatment and cut.

All treatments resulted in highly significant (P<0.001) increases in consumer sensory MQ4 values relative to control samples. The rump and striploin muscles were cooked and tested as grills and roasts whereas the oyster blades were cooked by the standard meat products cook chill process and reheated for consumer assessment, in accordance with instructions on ready meal packaging. Results across all cooking methods and muscles are shown in Fig. 55.

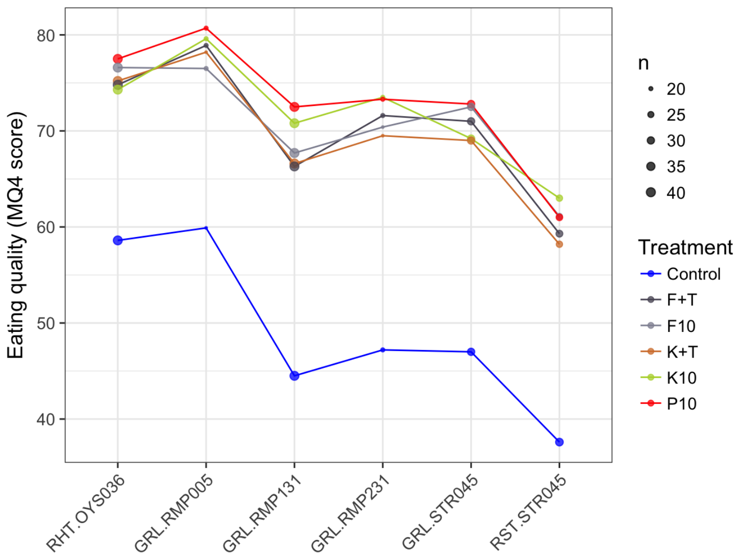


Figure 55. Mean eating quality (MQ4) values for control and treated samples by muscle, cooking method and treatment.

The raw mean (MQ4) score difference between control and treated samples within each cut by cook combination ranged from 16.2 to 28 points. The standard deviation was also typically reduced within the treated samples. There were no significant differences between treatments when controlling for cut and cook (P<0.294).

It was also observed that the large MQ4 value increases were mirrored by the individual MQ4 components with tenderness and flavour each increasing in tandem, as shown in Fig. 56. Somewhat surprisingly, given the moisture addition associated with treatments, juiciness was found to be less responsive. The juiciness values were noticeably low relative to other sensory traits for both control and treated samples in the roasts indicating that they were overcooked. While not reaching significance the P10 treatment was typically slightly higher for grill and reheat cooking methods while K10 outperformed in the roasts. The tenderised treatments were lower in each method.

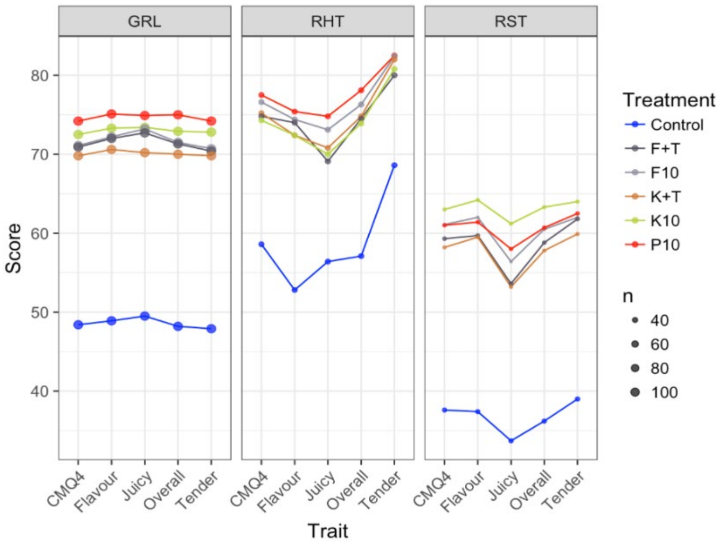


Figure 56. Mean MQ4 eating quality component values for control and treated product within cooking method.

Given the variation in weight added by treatments within muscle the potential for an interaction with eating quality was examined and found to be significant within the striploin but not in the rumps or oyster blades. The striploin relationship for each treatment is displayed in Fig. 57.

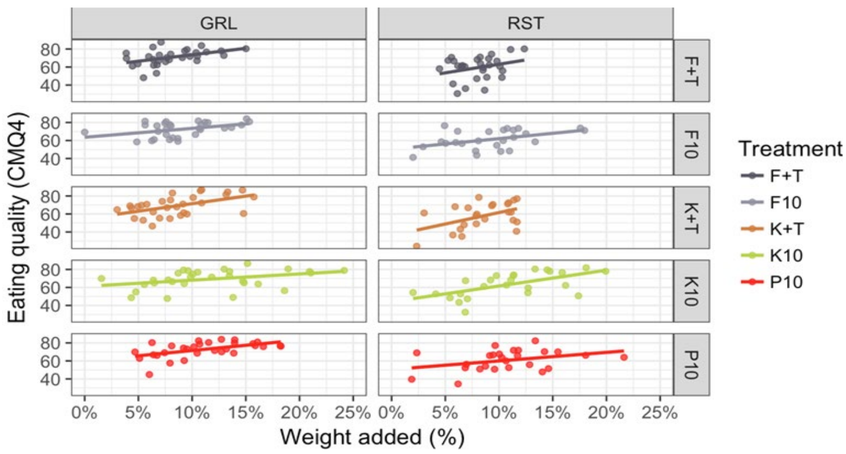


Figure 57. Relationship of eating quality (MQ4) and weight addition for striploin by treatment

The trend lines indicated that the relationship was heavily impacted by the lower pump rates of 5 to 7% with analysis determining no significant relationship between percentage weight added and eating quality above 7%. This suggested that there was a minimum threshold above which there was no further improvement.

No difference in treatment effect was found between cuts from grain and grass fed groups with similar improvement in the order of 20 MQ4 points. The initial raw material MQ4 value did however relate to the treated MQ4, with treated product from higher MQ4 raw material scoring higher than that with a lower initial value, as illustrated for striploin in Fig. 58 with the shaded area around the trend line illustrating the 95% confidence interval for predictions from the linear model. (Any horizontal line that remains within the shaded area represents a non-significant difference)

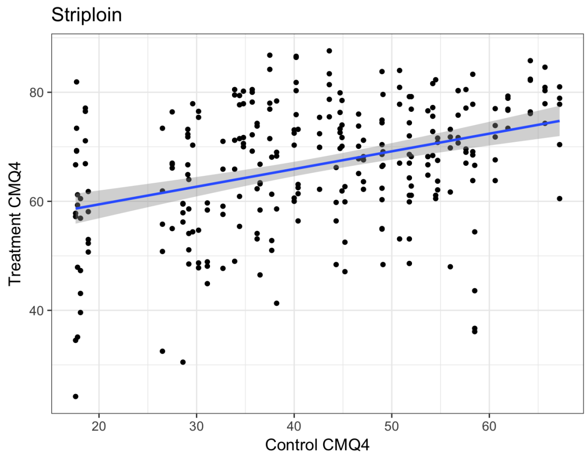


Figure 58. Relationship of control and treated sensory scores (MQ4)

The positive trend between raw material eating quality and eating quality after treatment was also found across the carcase grade categories as shown in Fig. 59, but with decreasing impact as the raw material improved. These results suggested that the there was a decreasing return to raw eating quality. Higher scoring product improved, but proportionally less than lower scoring product. These results indicated that the treatment process could be harnessed to deliver a more consistent consumer experience. Low scoring products tended to result in highly variable consumer eating experiences, however, the treatment process boosted scores across the scale at a decreasing rate so that the final treated product had a much tighter and higher MQ4 range than the paired untreated controls.

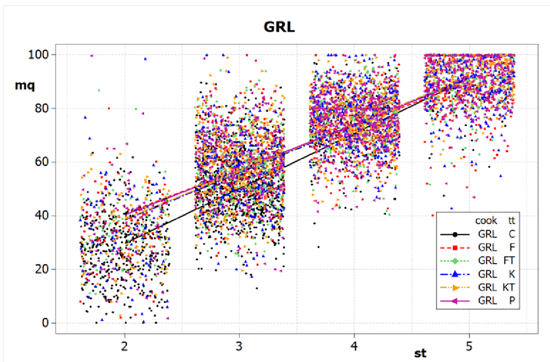


Figure 59. Relationship between source carcase grade and treated eating quality score (Grill)

Willingness to pay (WTP) data was collected from all consumers. The WTP question was presented after all 7 sensory samples had been evaluated to avoid price influencing sensory response. Results were recorded in $ per kg online scales for each category choice (unsatisfactory, good every day, better than everyday and premium) with the scale $0 to $80 per kg. The responses to the WTP question were typical of other MSA tested Australian consumers with ratios relative to 3* of around 50% for unsatisfactory, 150% for 4* and 200% for 5*, as shown in Table 29.

Table 29. Willingness to pay values and ratios relative to 3* (good everyday) value.

	$/kg				
	Fail	**3***	**4***	**5***	**N**
Grill	$8.67	$17.92	$26.70	$37.70	1,080
Roast	$9.36	$17.97	$27.09	$38.48	300
Reheat	$9.64	$18.37	$25.69	$33.99	420
	% of 3* price ($/kg)				
Grill	48%	100%	149%	210%	
Roast	52%	100%	151%	214%	
Reheat	52%	100%	140%	185%	

The category chosen for each sample by each consumer (10 consumer scores per sample) was then related to the price elected for that category by that consumer and used to produce a WTP for the control and treated products. The results, shown in Fig. 60, indicated a $5.00 to $10.00 /kg premium for an enhanced product due to the increased eating quality delivered and provided strong support for the economic case to pursue development and marketing of a processed meat product.

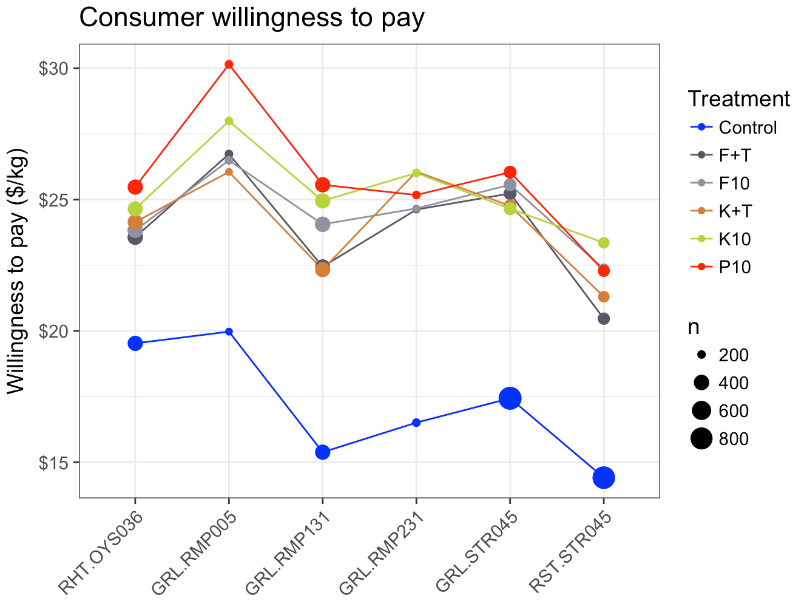


Figure. 60. Willingness to pay for control and treated products.

However, given that the typical enhanced improvement was found to be 20 MQ4 points or more, virtually all enhanced products would be expected to be a full MSA grade equivalent above controls which, from table 7, would equate to a 50% to 100% variation from the “good everyday” 3* value.

As the actual difference appeared slightly less than this, the MQ4 weightings and grade cut-off values were further investigated with results shown in Table 30.

Table 30. MQ4 sensory component weightings and category cut-off scores.

	Grill		Reheat		Roast	
No of observations	*1650*	*5390*	*390*	*1970*	*840*	*1320*
Treatment	Control	Enhanced	Control	Enhanced	Control	Enhanced
Tender	36	26	8	7	9	15
Juicy	8	8	7	12	31	18
Flavour	27	34	51	48	39	38
Overall	29	32	34	33	22	29
2*/3* cut-off	40	46	45	50	35	40
3*/4* cut-off	62	67	65	71	60	64
4*/5* cut-off	78	82	80	85	75	82
Accuracy 4 variable	68.3	66.2	57.9	57.9	74	68.3
Std MQ4 accuracy	67.6	64.9	54.9	57.1	73.9	67.6

This analysis provided valuable insight into apparent differences in consumer assessment of enhanced versus control product that needed to be considered in developing brand standards and a potential value adding model. The relative MQ4 cut-off values for enhanced relative to control products were around 5 points higher within each cooking method, explaining the earlier discrepancy between WTP $ and observed improved MQ4 values. This indicated that a higher MQ4 cut off value was required for an enhanced product to be rated as 3*, 4* or 5* relative to untreated "natural" control product.

Further insights were gained on examination of the MQ4 sensory trait weightings. The numbers in Table 30 against each trait (tender, juicy, flavour, overall) reflect the optimal proportion of each trait to combine in an MQ4 score for these data. Due to a generally strong correlation between the traits these weightings can safely be rounded to the nearest round number divisible by 10, reflected in the current MSA standards of 30:10:30:30. The enhanced grill values also fitted the general model, but less convincingly with signs of a trade-off from tenderness to flavour.

The re-heat weightings were quite different and massively weighted to flavour for both the control and treated samples. As all product was oyster blade and essentially 3* and 4* for the control it is possible that the low tenderness weighting reflected that tenderness was not an issue, but this would need replication to make any firm conclusion. The re-heat protocol was developed within the project as pre-cooked and re-heated product had not been tested by MSA previously. Given the high consumer satisfaction generated and the apparent weighting on flavour more work on this product category was recommended after examination of flavour chemistry results from AFBI. There was evidence that the industrial cooking process modified the relationship between sensory traits with an associated need to re-evaluate overall sensory relationships.

The roast results as noted earlier were abnormally low leading to a tentative conclusion that the samples may have been overcooked due to their small size despite adherence to MSA temperature standards and protocol. Again, the weighting to flavour is high relative to tenderness and similar for control and treated product. Juiciness also increased considerably for the roast weightings and more so for the control which would appear to support the assumption that the small size and associated short cooking time (at the 160˚C protocol) may have resulted in a dry overcooked product, with the added moisture in the enhanced samples reflected in the lower juiciness weighting. Further work post flavour analysis was recommended to examine the issue further.

The "Accuracy 4 variable" values in Table 30 represent the % of consumer responses allocated correctly to the grades using an optimum weighting for this specific set of data whereas the "Std MQ4 accuracy" reflects the equivalent accuracy for the standard MSA 30:10:30:30 weightings. It should be noted that the % is a reflection of consumer variance and not related to model accuracy; rather it is a measure of how well a "perfect" model could perform given inherent consumer variation. The 4 variable and standard weightings are seen to perform similarly despite the unusual weightings. This consumer variance measure was similar to other MSA based fresh untreated beef data with the overall scale contributing to the standard MQ4 performance.

From prior MSA experience the overall scale reflects "something else" rather than the net effect of tenderness, juiciness and flavour with the addition of the overall scale improving the precision of the MQ4 statistic rather than being an equivalent rating. In this case, the overall weighting was thought to reflect a consumer view that, while the enhanced product was highly acceptable, it differed in some way from typical fresh untreated beef. Despite rating enhanced samples higher for tenderness and flavour consumers demanded a higher score before granting a higher rating relative to untreated product, scored much lower by the same consumers.

This was noted as deserving further attention in conjunction with flavour chemistry to ensure the observation was understood and applied but suggested that enhanced product should perhaps be marketed as a separate category with a different branding proposition to the fresh beef offer. The product scored highly, significantly above controls, and the WTP values were higher providing an opportunity to build a successful proposition if positioned as a standalone product rather than as another form of fresh beef that is perhaps "NQR" (not quite right) or more correctly not quite the same.

The results also raised the question of whether the scoring difference might reflect a perceived "unnatural" taste arising from either the enhancement solution or process and a related question as to whether a "natural" flavour might result in cut-off values equivalent to untreated product. Flavour chemistry was conducted at AFBI in Belfast to further investigate these issues. The compounds analysed in the headspace from each beef sample are listed in Table 31, together with their retention times (RT), linear retention indices (LRI, a standardised indicator of elution time relative to alkanes) and comments on their origin and relevance.

Table 31. List of flavour chemistry compounds quantified.

Compounds	Mean RT	Mean LRI	Literature LRI	Ident. Method**	Formation
Short chain ketones					
2,3-Butanedione	1.35	<700	596	lri+ms	From Maillard reaction
2-butanone, 3-hydroxy	3.09	705	718	lri+ms	Maillard sugar and amino acids.
2-butanone	1.44	<700	572	lri+ms	From Maillard reaction
Strecker aldehydes					
2-Methyl butanal	2.25	<700	652	lri+ms	Strecker aldehyde. Marker for Maillard reaction.
3-Methyl butanal	2.15	<700	646	lri+ms	Strecker aldehyde. Marker for Maillard reaction.
2-Methyl propanal	1.28	<700	637	lri+ms	Strecker aldehyde. Marker compound for the Maillard reaction
Benzaldehyde	11.34	957	996	LRI+MS	Strecker aldehyde. Marker for Maillard reaction.
Other Maillard					
Dimethyl trisulphide	11.58	965	984	lri+ms	From Maillard reaction
Dimethyl disulphide	4.04	731	785	LRI+MS	From Maillard reaction
2,5-dimethyl pyrazine	10.11	911	892-913	LRI+MS	Maillard - sugars and amino acids.
3-Ethyl-2,5-dimethylpyrazine	14.22	1072	1093	lri+ms	Maillard - sugars and amino acids.
n-Aldehydes					
Pentanal	2.65	<700	697	LRI+MS	From thermal breakdown of lipids.
Hexanal	6.00	785	798-802	lri+ms	From thermal breakdown of lipids.
Heptanal	9.57	893	892-908	lri+ms	From thermal breakdown of lipids.
Octanal	12.51	1000	1002-1005	LRI+MS	From thermal breakdown of lipids.
Nonanal	14.93	1102	1107	LRI+MS	From thermal breakdown of lipids.
Decanal	16.87	1204	1209	lri+ms	From thermal breakdown
Alkanes and ketone					
Heptane	2.73	<700	700	lri+ms	
Octane	6.04	786	800	lri+ms	
Nonane	9.38	893	900	LRI+MS	
2-Heptanone	9.42	888	898	LRI+MS	Lipid oxidation
Acids					
Nonanoic Acid	17.98	1260	1275	lri+ms	
Hexadecanoic Acid	28.94	1958	2010	lri+ms	
Octadecanoic Acid	30.73	2161	2200	LRI+MS	
Pentadecanoic Acid	27.65	1855	1820, 1851	lri+ms	
Miscellaneous					
Toluene	4.60	747	774	LRI+MS	
1-Octene	5.347	777		lri+ms	
Alpha pinene	10.55	927	939	lri+ms	*Olive oil spray?
camphene	11.00	944	953	lri+ms	*Olive oil spray?

** LRI = linear retention index.*

*** Identification method: MS or LRI = mass spectrum or linear retention index compared with authentic compound; ms or lri = mass spectrum or linear retention index compared with literature values.*

The analysis of volatile compounds showed clear effects of muscle but, surprisingly, the effects of enhancement treatments were generally small. Several possible explanations were reported:

- Enhancement by injection being inherently inhomogeneous, with injections sites potentially being most affected and the regions in between less so.
- Enhancement affecting flavour volatile formation by several mechanisms such as (i) addition of new components which themselves add flavour or may react with components of the meat to give flavour, (ii) dilution of existing meat flavour precursors by added liquid, (iii) inhibition of the Maillard reaction due to greater water activity. The combined effect of these mechanisms may have variable effects on the volatile compounds.

In contrast, analyses for sugars and sugar phosphates showed clear effects of enhancement with increasing sugar concentrations for all enhancement procedures. In addition, a new sugar was identified, not detected in control beef. In contrast, sugar phosphates were reduced by enhancement processes. These results suggested that either there were considerable concentrations of sugars in all these samples (including the phosphate treatment, P10) or that the conditions caused by these treatments were conducive to the biochemical formation of additional sugars. The sugar differences were evident in the GCMS output contrasting a control sample shown in Fig.61 with a phosphate treated sample in Fig. 62.

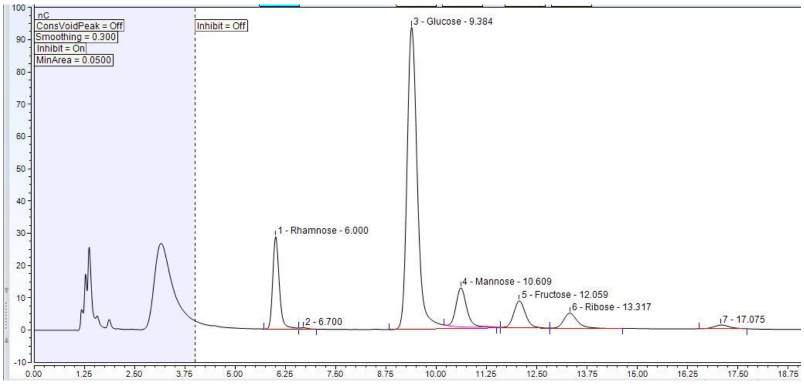


Figure 61. Chromatogram for control beef – S2W7

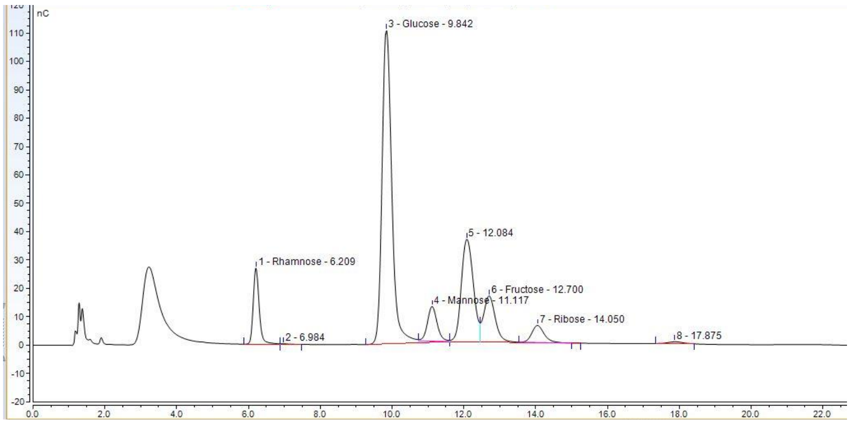


Figure 62. Chromatogram for P10 beef – G2F1

The control sample (Fig. 61) shows the expected peaks for glucose, mannose, fructose and ribose together with rhamnose (internal standard) and contrasts with Fig. 62 (Note additional peak at 12.0 after Manose).

As the project and previous MSA studies had shown a substantial increase in consumer scores, including the scores for flavour liking, the flavour chemistry analysis sought to establish "Why" and "How". Clear muscle effects were established for volatile (aroma) compounds, but these were unexpectedly less affected by the enhancement products. As flavour is a combination of taste and aroma it was possible that taste compounds were responsible for the flavour change. An addition of salt (NaCl) would produce a taste effect and it was noted that many consumers noted a salty taste. A similar effect could result from an increase in certain amino acids and peptides from the enzymic activity of the kiwi and ficin.

Flavour development is a complex process influenced by composition of the raw muscle with many compounds and pH acting as flavour precursors that interact with cooking type and temperature to produce the consumer perceived flavour, influenced by both base taste compounds and particularly by aroma from volatiles. Enhancement treatments provided further interaction possibilities.

If the significant differences in sugars, or indeed the volatile compounds, could be shown to link to the consumer scores for flavour, this might suggest a promising route for influencing flavour with new and modified enhancement treatments. The concept of controlling, or at least significantly modifying, flavour outcomes by adjusting flavour precursors and cooking process was considerably evolved through the AFBI analysis and extended in later studies.

Results from this study were reported in the P.PIP.0503 and presented to meat products and production teams in several workshops and seminars.

4.3.2. Evaluation of potential “clean label” enhancement solutions

This project, conducted in conjunction with Texas Tech Meat Science, expanded examination of potential enhancement products to include some natural alternatives that would enable “clean” labelling. A consideration was the possibility that a more natural meat taste might address the different sensory and willingness to pay relationships found in the preceding processed meat project.

A structured extreme range of grass and grain fed raw material sourced from Australia and USA was utilised to ensure any initial MQ4 and process interactions could be examined. The treatments applied were:

1. Untreated control sample (coded G01).
2. Phosphate based enhancement at 10% pump rate reflecting common USA practice (G02).
3. A commercial natural beef stock product at 10% pump rate applied precooking (G03).
4. Sodium carbonate (soda ash) in solution at a 10% pump rate (G04).
5. Sodium bicarbonate in solution at a 10% pump rate (G05).
6. A natural modified potato starch product at 10 % pump rate (G06).

The phosphate treatment was selected as the typical commercial benchmark, known to work but carrying ingredient labelling concerns for some consumer groups. Sodium carbonate was used in some USA enhancement systems but labelled usage suggestions such as glass manufacture were not attractive whereas the beef stock, bicarb soda and potato starch provided potential natural and clean label potential.

A range of muscles were included from all cattle classes and grill, roast and stir-fry cooking methods planned. Only the grill method was completed due to financial constraints but the roast and stir-fry product remains in frozen storage at TTU and able to be tested when desired. Paired untreated cuts are also in frozen storage at UNE to enable paired comparison with Australian consumers. Striploin, cube roll, knuckle and eye round primals were collected for the enhancement study with ribs and briskets also collected for associated study of a Texas BBQ cooking process.

Results are reported for the USA tested grilled product which included *M.longissimus dorsi* (cube roll and striploin) and *M.semitendinosus* (eye round). The *M.spinalis dorsi* (spinalis) muscle was removed from the cube rolls and tested as a non treated high quality benchmark. Eye rounds were utilised from all Australian and USA quality subsets from high end grain and grass fed to manufacturing cow. The *M.longissimus dorsi* (LD) samples were sourced from USDA Prime, Choice and Select graded beef and from the non MSA lower value add and manufacturing category Australian product, with the LD from the 3 higher MSA graded categories utilised in an Australian packaging study. This provided an extreme raw material quality range across both muscles displayed by feed type and quality graded category in Table 32.

Table 32. Grilled samples tested by source quality grouping within animal feed type

	Australian MSA Graded									USDA Grades			
Feed	**504.1**	**504.2**	**504.3**	**504.4**	**504.5**	**504.6**	**504.7**	**505.1**	**505.2**	**508.1**	**508.2**	**508.3**	**Total**
Grain	34	0	36	0	36	0	114	0	0	120	172	170	682
Grass	0	36	0	36	0	36	0	113	141	0	0	0	362
Total	34	36	36	36	36	36	114	113	141	120	172	170	1044

Table 33 presents the count of grill samples within each treatment. Treatments were applied "within animal" and rotated across cut position to ensure a balanced comparison.

Table 33. Number of grilled sensory samples tested by muscle and treatment

Muscle Code	G01	G02	G03	G04	G05	G06	Total
CUB081	23						23
EYE075	94	94	96	94	91	91	560
STR045	78	78	77	76	75	77	461
Total	195	172	173	170	166	168	1044

The resulting MQ4 values for each muscle by treatment combination are depicted in Fig. 63, with the relative treatment results appearing very similar for both cuts, confirmed by the lack of a statistical cut x treatment interaction.

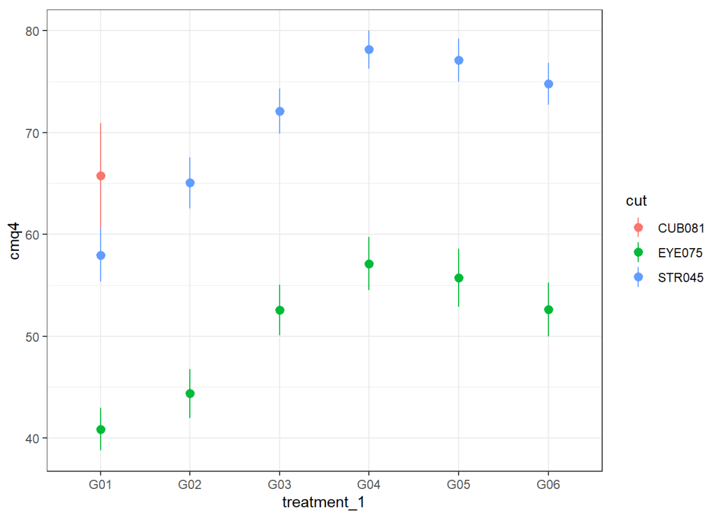


Figure 63. Sensory mean scores (MQ4) and standard deviation by cut, control (G01) and enhancement treatment

While the statistical analysis indicated significant differences for cut, treatment and feed the feed difference is considered unreliable, likely reflecting the different cut x cattle populations with no grass fed USA stock and no MSA level striploin in the Australian grass or grain and no USA grain fed cuts below USDA Select. From the very similar MQ4 pattern across treatments for grass and grain fed product in Fig. 64 a genuine feed effect is considered unlikely.

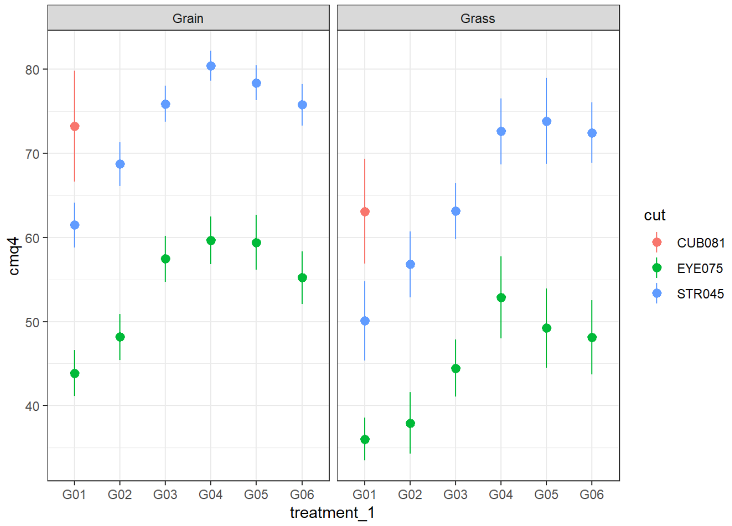


Figure 64. Sensory mean scores (MQ4) and standard deviation by cut, control (G01) and enhancement treatment within animal feed type

Treatment means for the individual sensory scales and the weighted MQ4 are presented in Table 34. The impressive response from the beef stock (G03) treatment exceeded expectations and together with the sodium bicarbonate (G05) and potato starch (G06) results provided an indication that a clean label product might be possible without compromising sensory outcomes.

Table 34. Raw treatment by muscle means for sensory traits

Treatment	Code	Muscle	n	Tender	Juicy	Flavour	Overall	MQ4
Control	G01	CUB081	23	75.7	73.9	58.7	62.5	65.7
		EYE075	94	39.1	42.3	41.1	40.6	40.9
		STR045	78	65.7	60.8	53.5	56.0	58.0
Phosphate	G02	EYE075	94	41.4	51.2	44.4	44.2	44.4
		STR045	78	70.9	71.5	60.7	63.9	65.1
Beef Stock	G03	EYE075	96	48.5	60.8	54.1	53.0	52.6
		STR045	77	76.2	75.1	70.0	72.1	72.1
Sodium Carbonate	G04	EYE075	94	56.5	61.5	57.6	56.8	57.1
		STR045	76	85.1	79.8	74.9	77.4	78.1
Bicarb soda	G05	EYE075	91	54.6	60.0	56.9	54.8	55.7
		STR045	75	83.8	79.7	73.5	76.3	77.1
Potato Starch	G06	EYE075	91	51.1	56.9	53.4	52.5	52.6
		STR045	77	81.6	77.0	71.3	73.8	74.8

Figure 65 displays a pairwise comparison between the control and each treatment.

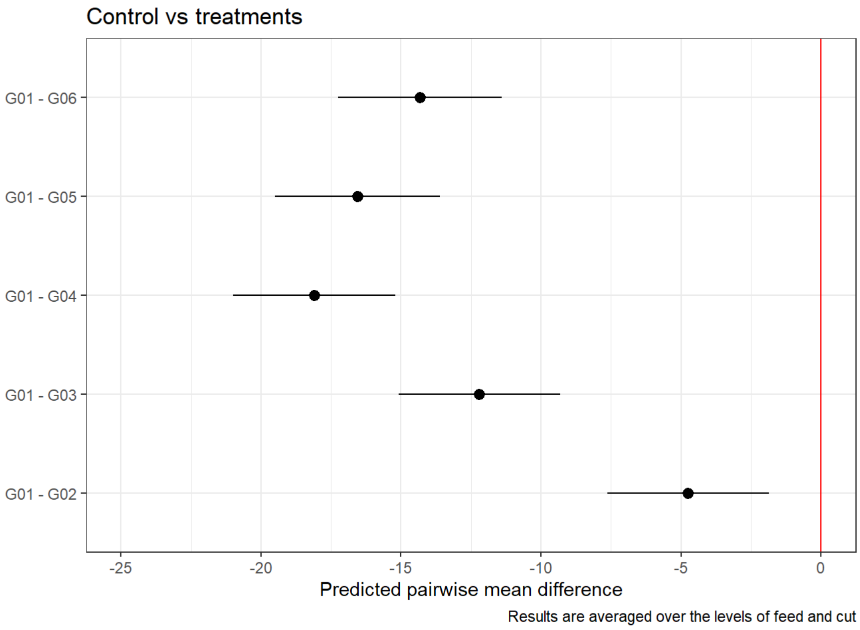


Figure 65. Predicted pairwise MQ4 mean difference between control and treated samples

The significant difference between all treatments and the untreated control (G01) was evident as was the non-significant difference between the potato starch (G06), bicarb (G05) and soda ash (G04) treatments. Again, the unexpected positive beef stock (G03) result was evident as was the equally unexpectedly lower ranking of the industry standard phosphate (G02).

Further important questions related to the impact of treatments relative to initial raw material quality MQ4 and on the individual MQ4 components of tenderness, juiciness, flavour and overall satisfaction. Treatment relationships to the raw material control MQ4 are presented in Fig. 66.

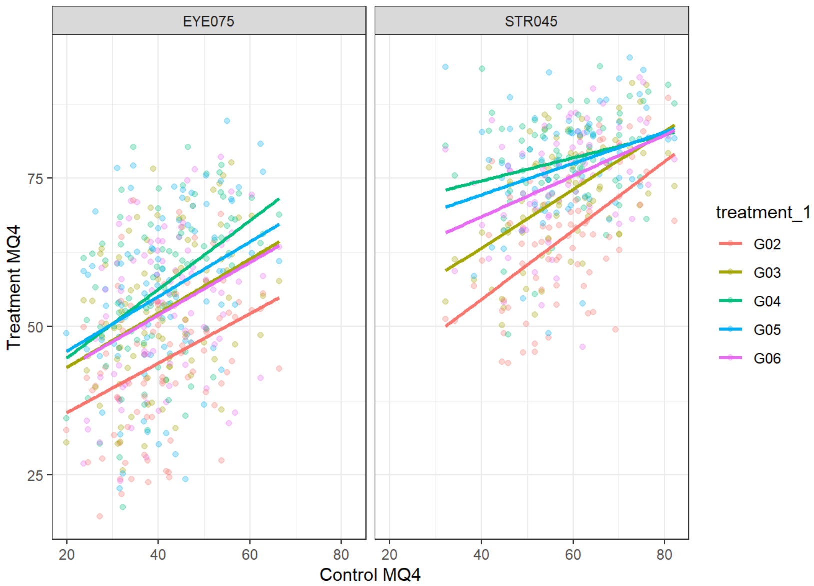


Figure 66. Relationship between control and treatment MQ4 by cut

These relationships suggested that the treatment impact was reduced as the raw material quality improved, particularly for the striploin. A similar response was found for tenderness, juiciness and flavour and confirmed by statistical evaluation which produced significant (P<0.001) effects at the lower control MQ4 level, reducing but still significant for moderate MQ4 controls and with little (striploin) to no (eye round) significance for the highest control MQ4.

Further insight was provided by investigating the relationship of the individual sensory scales as displayed in Fig. 67, and by examining the individual scale relative differences within treatment and cut as illustrated by Fig. 68.

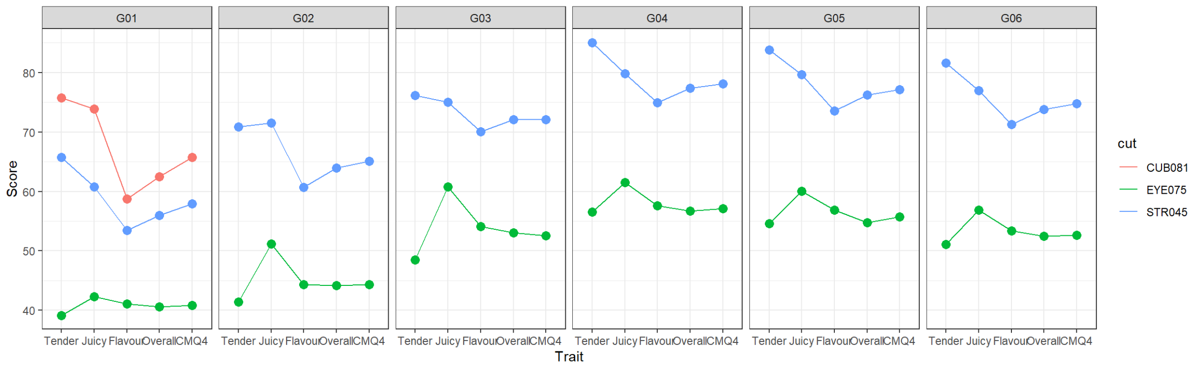


Figure 67. Mean MQ4 sensory scale values for treatments and cut

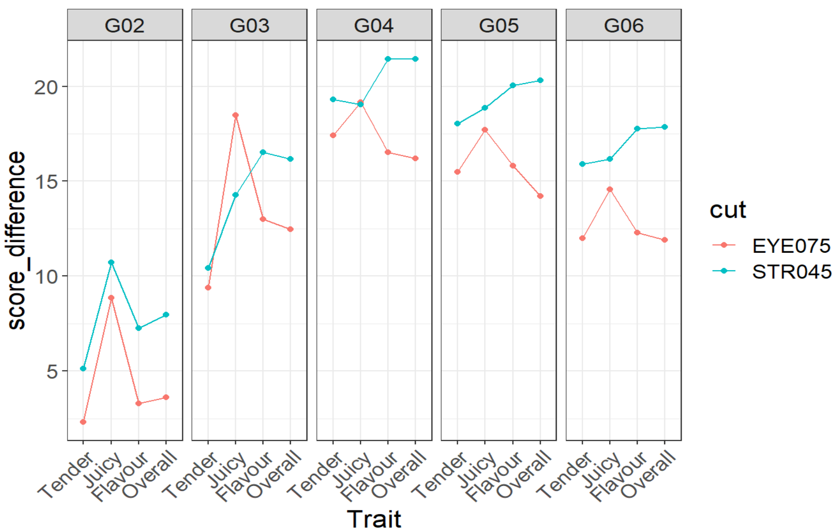


Figure 68. Score differences (treatment – control MQ4) for sensory traits by muscle and treatment

From Fig. 68 it was observed that the treatment effect differed by treatment type and muscle. Whereas the phosphate (G02) dramatically improved juiciness, tenderness was less impacted and flavour intermediate. The larger impact on juiciness was common for all treatments of eye round but not for striploin where flavour was increased more than tenderness or juiciness by all treatments other than G02.

While the modified potato starch results were similar to the soda ash, bicarb and beef stock practical difficulties were encountered in mixing the material and retaining it in suspension during injection. This issue and potential consumer interpretation of “modified” resulted in the natural beef stock and sodium bicarbonate, a traditional home kitchen ingredient, being considered prime candidates for further research effort directed to commercial application.

It had been hoped that beef stock injection might improve flavour but no tenderness improvement was expected, with a combination of sodium bicarbonate and beef stock a working hypothesis to modulate both attributes. Extension of this hypothesis included potential flavour intensity manipulation through varying reduction during the stock preparation. These issues are developed further within the discussion section relating to the value adding studies.

4.3.3. TTU Fajita enhancement project

A fajita enhancement TTU graduate student project was conducted within the program utilising a range of muscles. Following the earlier enhancement work an untreated control was evaluated against the same tripolyphosphate (G02) and sodium bicarbonate (G05) treatments used previously. Given the practical difficulty of injecting these small muscles the enhancement solutions were added through vacuum tumbling. Table 35 shows the pH, green and processed weights and percent take-up of solutions.

Table 35. The main effects of muscle and enhancement on processing characteristics of muscle samples (n = 216)[1.]

Treatment	Code	Post-processing pH	Green weight, kg	Tumbled weight, kg	Pickup %
Muscle					
Thick Skirt	DIA092	5.78[d]	0.29[c]	0.33[c]	15.9[a]
External Flank Plate	TFL051	5.92[bc]	0.47[b]	0.53[b]	12.8[b]
Internal Flank Plate	TFL052	6.06[a]	0.62[a]	0.70[a]	12.9[b]
Flank steak	TFL064	5.95[ab]	0.33[c]	0.35[c]	7.2[d]
Topside cap	TOP033	5.81[cd]	0.51[b]	0.56[b]	9.6[c]
SEM[2]		0.429	0.02	0.22	0.49
P-value		< 0.01	< 0.01	< 0.01	< 0.01
Enhancement					
Bicarbonate of Soda		6.43[a]	0.45	0.5	11.8
Phosphate		5.84[b]	0.44	0.5	11.5
Control		5.43[c]	--	--	--
SEM		0.328	0.012	0.013	0.3
P-value		< 0.01	0.96	0.96	0.52
P-value (muscle × enhancement)		0.16	0.65	0.73	0.1

[a-d] Within a column, least squares means without a common superscript differ ($P < 0.05$) due to muscle.

[1] Muscle: outside skirt (n = 42), inside skirt (n = 42), bottom sirloin flap (n = 44), flank (n = 44), inside round cap (n

[2] Pooled (largest) SE of least squares means.

The effect of enhancement treatment on cooked moisture is shown in Table 36 and indicates a consistently higher cooked moisture across all muscles with bicarbonate of soda despite the very similar pickup% observed in Table 35.

Table 36. The interactive effects (P < 0.01) of muscle and enhancement on cooked moisture % of muscle samples (n = 216)

Muscle	Bicarb Soda	Phosphate	Control
Thick skirt	62.5^{cdef}	57.8^{g}	50.6^{h}
External Flank Plate	66.4^{a}	62.1^{def}	55.5^{g}
Internal Flank Plate	64.8^{abc}	62.8^{cde}	57.1^{g}
Flank steak	64.2^{abcd}	61.8^{ef}	57.7^{g}
Topside cap	65.3^{ab}	64.0^{bcde}	60.3^{f}
SEM [2]	0.97		

The sensory results (MQ4) are presented in Table 37.

Table 37. Mean sensory (MQ4) values by treatment and muscle

Cut	Code	Control	Phosphate	Bicarb Soda	All
Thick Skirt	DIA092	45.1	66.4	64.4	58.2
External Flank Plate	TFL051	40.2	62.5	64.2	56.2
Internal Flank Plate	TFL052	58.7	78.7	76.5	71.6
Flank steak	TFL064	39.4	60	65.4	54.8
Topside cap	TOP033	35.2	54.5	62.6	50.7
	All	43.6	64.6	66.7	58.3

Both enhancement treatments produced significantly better sensory results than the control with no significant difference between the two.

While the MSA standard MQ4 weightings of 0.3 tender, 0.1 juicy, 0.3 flavour and 0.3 overall performed equally well in predicting 3*, 4* and 5* categories, weightings for this study of 360 consumers indicated an ideal transfer of 0.1 from tenderness to flavour, making flavour effectively double the importance of tenderness. More data was required to determine if this might relate to either fajita product and cooking practice or to an enhancement effect.

Category cut-off values were also similar to typical non enhanced product cooked by grill, roast or stir-fry methods for Texas consumers with minimum MQ4 values of 40.8 for 3*, 64.8 for 4* and 82.9 for 5*. From Table 37 it was observed that both enhancement treatments raised the mean MQ4 average values from a low 3* category to low 4*.

Average willingness to pay values were also within previously observed USA consumer range with unsatisfactory product rated at 41% of 3*, 4* at 163% of 3* and 5* at 237% of 3* values. From these results an enhanced product could be priced at a significant retail premium with the moisture pickup likely to offset the enhancement cots.

4.3.4 Meat colour, pH, dentition and packaging.

This project, initiated to investigate grass fed bullock MSA meat colour non-compliance issues, evolved to have far reaching consequences in relation to both meat colour and packaging with highly significant impact on the MSA program.

As detailed in the methodology section tenderloins, striploins and rumps from 48 bodies/96 sides were collected representing a controlled matrix of dentition, loin pH and AUS-MEAT meat colour (AMC) at grading. Meat colour and pH relationships for each cut was progressively assessed immediately post boning, after primal ageing in vacuum packaging prior to retail packing, by consumer evaluation and finally after a retail display period.

4.3.4.1. Meat colour at grading, boning and retail packing.

Clearly consumer assessment of meat colour could not be made prior to retail display with AMC and HunterLab values were used to compare colour at grading (striploin only), all cuts at boning, after each ageing period during retail packing (pre-retail) and post retail.

When AMC at grading was compared with AMC at boning it was found that while there was a relationship in striploin (STR) at boning no relationship was found in rump (RMP) or tenderloin (TDR) as illustrated in Fig. 69.

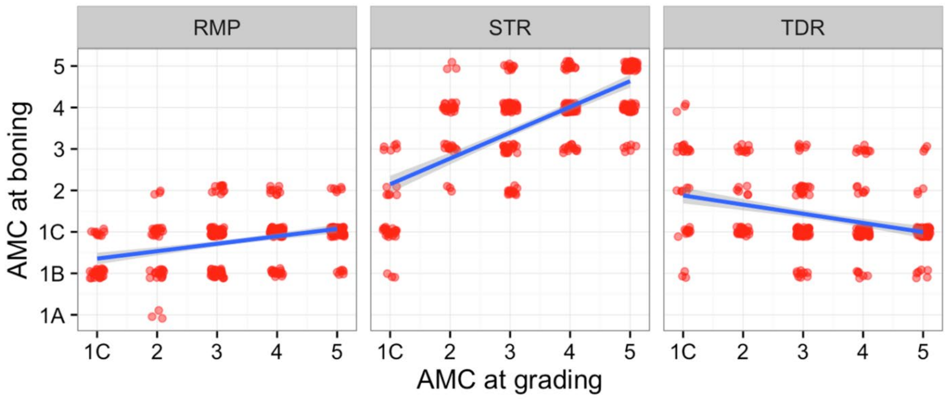


Figure 69. AMC at boning vs AMC at grading by cut.

Fig. 69 illustrates the substantial variance between the official MSA meat colour assessment and that of individual cuts made by the same highly experienced grader a few hours later for each cut. There was a moderate relationship for striploin where the measurement site is the same, although scores were distributed widely within each original class, but a very poor relationship between the striploin colour at grading and rump or tenderloin score at boning.

It was further noted that despite the high proportion of carcasses selected as having meat colour above 3 and or pH greater than 5.7 no rumps and only two tenderloins from the same carcasses had an AMC above 3. This indicated that, for colour at least, the tenderloins and rumps excluded from MSA due to striploin meat colour in fact had acceptable AMC at boning. In essence there was practically no relationship between striploin AMC at grading and AMC for the other cuts at boning. On the basis of these data AMC at grading was found to be ineffective as an indicator of AMC post boning with correlations of 0.391 (STR), 0.224 (RMP) and -0.248 (TDR).

When AMC at boning was compared with AMC pre-retail, after primal ageing of 5, 12 or 40 days, it was found that the striploin AMC tended to get lighter, while rump and tenderloin tended to get darker, as illustrated in Fig. 70, causing the individual cut meat colours to become more aligned on average after primal ageing. While the striploin correlation was strong at 0.768 it was moderate for rump at 0.409 and close to non existent (0.092) for tenderloin.

There was little difference between AMC at boning and AMC pre retail for groups either side of pH 5.7 although the two categories remained different.

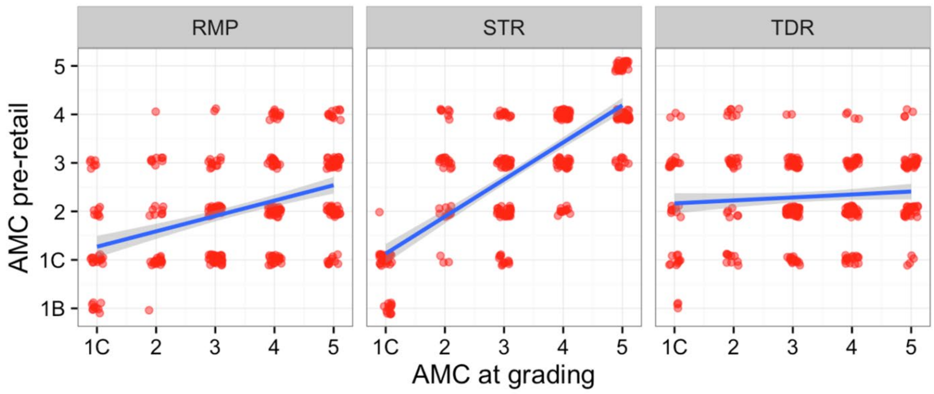


Figure 70. AMC pre-retail vs AMC at grading by cut

Table 38 displays correlations between AMC at grading (striploin), boning, pre retail and post retail.

Table 38. Correlations by cut between AMC at grading, boning, pre and post retail packaging.

STR	**AMCgrade**	**AMCbone**	**AMCpre-retail**
AMCb	0.692		
AMCpre	0.768	0.638	
AMCpost	0.663	0.494	0.662
RMP	**AMCgrade**	**AMCbone**	**AMCpre-retail**
AMCb	0.360		
AMCpre	0.409	0.446	
AMCpost	0.362	0.279	0.359
TDR	**AMCgrade**	**AMCbone**	**AMCpre-retail**
AMCb	-0.341		
AMCpre	0.092	0.345	
AMCpost	0.123	0.188	0.225

It is seen that the correlations for STR were generally high and larger than for the other cuts: for STR around 0.65, for RMP around 0.35 and for TDR around 0.20, though with more variation. The strong negative correlation for TDR between AMC at grading & AMC at boning was unusual (partly explained by the odd result for one carcase). For each cut the correlation of AMC pre retail with AMC at boning was greater than the correlation of AMC post retail with AMC at boning.

4.3.4.2. Consumer assessment of Meat colour – the CMC score

Given that the industry interest in meat colour and its inclusion as an MSA grade pre-condition related to the importance of meat colour as a factor strongly related to consumer retail purchasing, a critical project requirement was to utilise untrained random consumers to measure retail meat colour by observing meat packs in a typical open fronted refrigerated display case.

To facilitate analysis and provide direct linkage to consumer outcomes a "Consumer Meat colour Score" (CMC) was developed from the consumer data linking the scores recorded to the category boxes selected across all 20,140 observations. Despite the overriding importance of consumer colour perception directly influencing purchase intent and pricing no previous consistent system of consumer reference was found with typical papers relating to instrumental, principally L*a*b* values or to hedonic scales particular to an experiment. While the majority of issues and recommendations within the American Meat Science Association (AMSA) Meat Colour Measurement Guidelines (2012) were adopted or addressed in the study design, a 100 mm line scale was utilised for consumer scoring rather than 7 or 9 point hedonic scales due to alignment with MSA sensory scale and category choice protocol.

Prior to adopting the CMC measure analysis was conducted on individual consumer data to determine the robustness of such a measure and its ability to define a purchase category. The dot plot in Fig. 71 relates individual consumer CMC to the category selected with 1 would definitely purchase, 2 would definitely purchase if discounted and 3 would definitely not purchase.

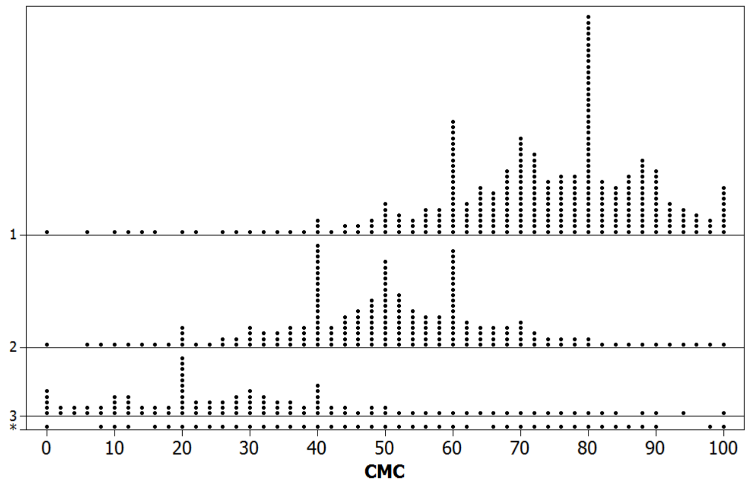


Figure 71. Consumer meat colour scores (CMC) in relation to purchase intent category.

The plots indicate a strong relationship and consistency between the two scales with a clear delineation of the purchase scale (PS) by CMC: higher CMC values are associated with PS=1, lower CMC values with PS=3. This was in accordance with expectation indicating that consumers were relatively internally consistent: they tended to choose a CMC value that matched their choice of purchasing category. A discriminate analysis was conducted to evaluate optimal cut off scores and establish their effectiveness in defining purchase categories. This produced cut-off values of 38.5

and 62.5 for CMC, with a 75% success rate (over all individual consumers who gave a valid response) as shown in Table 39.

Table 39. Discriminate analysis of CMC as a predictor of purchase category

	True Group			
Assigned Group	**1**	**2**	**3**	Total N
1 (CMC < 38.5)	8356	1093	82	9531
2 (38.5 < CMC < 62.5)	2204	4246	559	7009
3 (62.5 < CMC)	102	974	2349	3425
Total N	10662	6313	2990	19965
N correct	8356	4246	2349	14951
Proportion	0.784	0.673	0.786	0.749

N = 19965 N.Correct = 14951 %.Correct = 74.9%

Thus, CMC (consumer meat colour liking) and PS (purchasing category) are reasonably consistent, and it was concluded that CMC could be used as a predictor of PS. This result is comparable with the MQ4 (consumer meat quality) used as a predictor of MSA grades. A further analysis question related to the use of mean versus clipped mean consumer scores for individual sample CMC arising from MQ4 practise in which the two highest and lowest scores are clipped to create a 10-4 clipped value from averaging the central 6. While the analysis found a similar wide range of consumer variation to MQ4 the distributions appeared normal and it was elected to proceed with a simple mean value without clipping for CMC.

The Consumer Meat Colour score (CMC) utilised for evaluation was the mean of the 10 individual consumer scores for each sample and utilised as the benchmark measure for comparison of all visual colour comparisons.

The relationship of CMC to demographic variables was also evaluated with these being:

1. Membership of organisation, charity or club (*46 groups, with 1-139 members*)
2. Gender (male, female)
3. Age group (*18-19, 20-25, 26-30, 31-39, 40-60, 61-70*).
4. Place of beef purchase (*butcher, supermarket, farmers' market, none*)

Each sample was assessed by ten consumers. The average of these was computed and then the deviation of the value assigned by each consumer from this average computed. While some demographic parameters were significant this was largely a consequence of the high number of observations and none were regarded as practically important given the typical small numerical difference of less than 2 CMC points and lack of convincing explanation for the minor charity group, gender, age or shopping habit differences.

In response to the question **"From where do you usually purchase your beef?** *(Use* **X** *in all applicable)*" 627/836 (75%) bought beef at a supermarket at least some of the time; 332/836 (40%) from a butcher and 37/836 (4.4%) from a farmer's market, while 51/836 did not purchase beef. While the mean scores were lower by several points for consumers purchasing from farmers markets this was also regarded as of limited importance and may reflect a general dislike of packaging.

This project utilised AMC and CMC to evaluate the impact of a number of factors that potentially might impact on consumer appeal in the retail case:

- AUS-MEAT meat colour assessed at MSA grading
- Individual cut AMC relationships at boning, prior to and post retail packing
- Dentition
- Effectiveness of AMC at boning versus pH as a predictor of CMC
- Packaging type (OWP, MAP and VSP)
- Days aged in vacuum packaging as a primal prior to retail packaging (5, 12 and 40)
- Days in retail packaging

4.3.4.3. CMC relative to MSA grading score, muscle, primal ageing period and retail pack

MSA grade eligibility required an AUS-MEAT meat colour score (AMC) of 3 or less. This standard had been applied from the commencement of MSA and, while not used in MQ4 prediction as no relationship had been found to eating quality, was adopted due to industry belief that consumers would not rate meat of AMC 4 and above as acceptable.

Fig. 72 graphically illustrates the observed CMC response to MSA grading by AMC chip. This graph includes all retail cut observations following industry practice and MSA requirements where the single LD reading was applied to the entire carcase and all cuts therein.

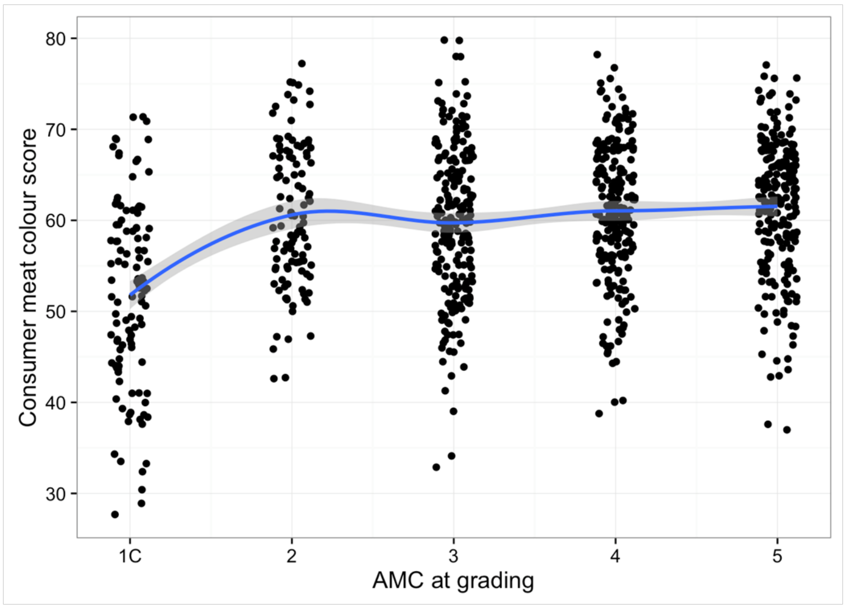


Figure 72. Consumer response (CMC) relative to AMC of striploin at MSA grading.

Contrary to expectation it was observed that consumers showed no discrimination between AMC 2, 3, 4 and 5 but discounted the lighter 1C. This finding was challenging but believed valid due to the strong balance within the experiment, large number of observations (20,140) and controlled display conditions where packs were displayed in an 8x8 Latin square relationship for all colour and pH combinations with tight control and balance of cabinet position for each cut set. The result is further illustrated by the box plots in Fig. 73.

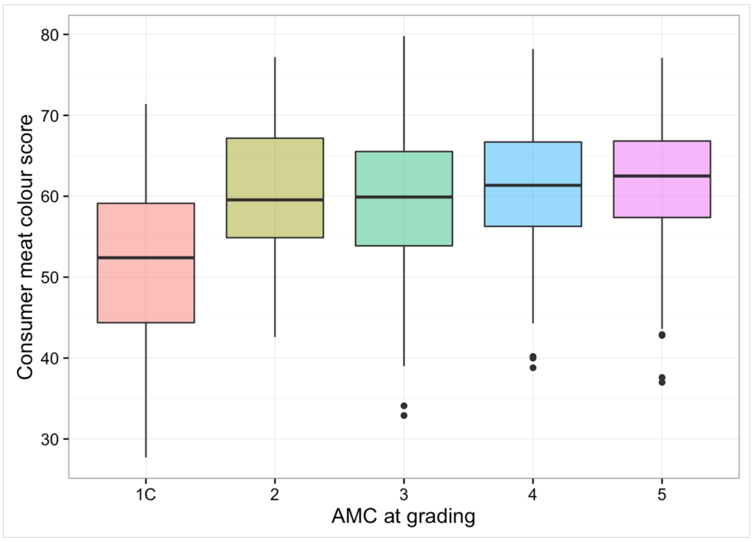


Figure 73. Consumer meat colour (CMC) score relative to AMC at MSA grading.

The AUS-MEAT meat colour scores for every primal, comprising 2 tenderloins, 2 striploins and 2 rumps each replicated 3 times due to slicing and transfer to OWP, MAP and VSP packs was also evaluated against the consumer CMC scores. The AMC readings were assigned to each pack after a standard 20 minute bloom period immediately before lidding or wrapping. The results, grouping each of the 3 primal ageing periods, are displayed graphically in Fig. 74.

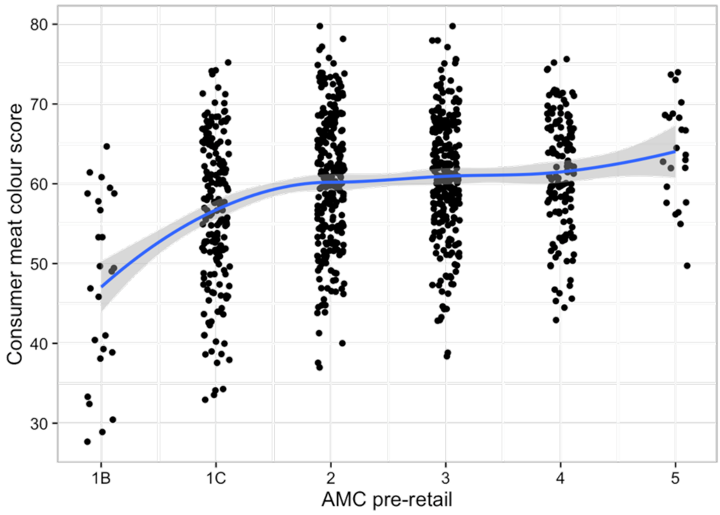


Figure 74. CMC and pre-retail AMC of individual retail trays incorporating 3 cuts and 3 replicates.

The graph indicated some movement in colour over the ageing period with a trend toward lighter colour seen in some 1B appearing and a reduction in AMC 5. The observed pattern between AMC and CMC remained however with the lighter colours scored substantially lower.

Industry conjecture regarding whether, when corrected for pH and meat colour, consumers perceived a meat colour difference between cuts sourced from 6 teeth carcasses relative to 4 and 2 teeth was evaluated within the designed cut collection. The results, depicted in Fig. 75, indicated that there was no dentition to colour relationship for the 2, 4 and 6 teeth categories. More detailed analysis demonstrated that the lack of relationship extended across those with pH above and below

5.7 and across all days from slaughter to consumer observation variations and all packaging types, established that dentition had no relationship to CMC.

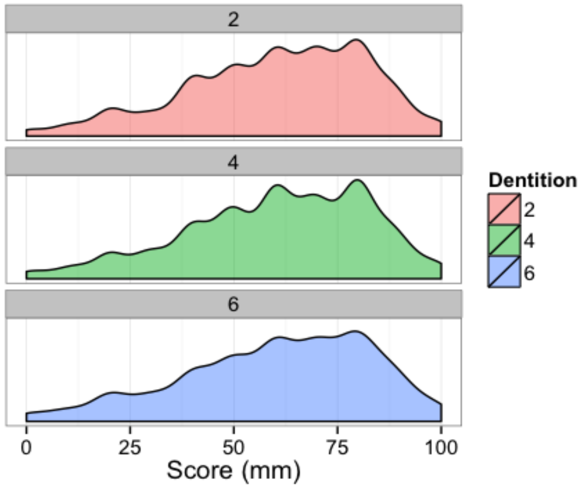


Figure 75. Distribution of CMC consumer scores within dentition categories.

The CMC data were further utilised to compare the effectiveness of the MSA grading standard of AMC less than 4 and pH below 5.71 to the use of ultimate pH alone, dentition having been ruled out. The analysis outcome is presented in Table 40.

	n	%
Total sample size	864	100%
pH < 5.71	666	77%
AMC < 4	432	50%
pH < 5.71 & AMC < 4	414	48%

	pH < 5.71 & AMC < 4		pH < 5.71	
	n	%	n	%
Definitely would buy	195	47%	357	54%
Definitely would buy if discounted	208	50%	297	44%
Definitely would not buy	11	3%	12	2%
Total	**414**	**100%**	**666**	**100%**

Table 40. Effectiveness of MSA grading criteria (AMC <4 and pHu <5.71) relative to use of pHu, <5.71 alone to predict CMC category.

The analysis results clearly indicted pHu alone provided at least equal consumer protection while rejecting less carcasses. This result reflected the changes in AMC observed after the MSA grading assessment relative to pHu which remained stable from grading to post retail.

As shown pHu used alone removed an equivalent number of unsatisfactory (Definitely would not buy) samples while more accurately segregating the definitely would buy category. On the basis of this outcome the Pathways Committee recommended that AMC be dropped as an MSA grading criteria while pHu of <5.71 be retained. This recommendation was accepted by the MSA Taskforce and endorsed by the AUS-MEAT Language and Standards Committee resulting in a change to the MSA standards.

This represented a major benefit to industry in increasing MSA compliance and supply while maintaining equivalent consumer outcomes.

4.3.4.4. CMC relative to retail packaging system

The OWP treatment was only displayed for one consumer observation period the day following retail packing whereas the MAP and VSP packs were observed at 3, 5 and 7 days post packing simulating retail distribution timing. Fig. 76 displays the CMC score distribution across all cuts, primal ageing and retail display periods for the three packaging systems. While OWP and MAP produced similar CMC score distributions the VSP boxplot is relatively, but not significantly, lower.

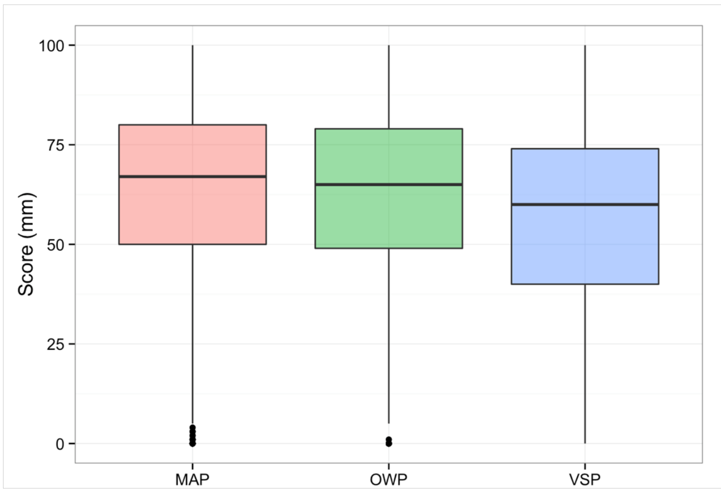


Figure 76. Consumer meat colour score (CMC) and packaging type

Fig. 77 provides more specific data relating CMC to each packaging type in relation to the three purchase categories. While consumers returned similar scores for the categories ‘Definitely would buy if discounted’ and ‘Definitely would not buy’ across all packaging types the VSP and OWP ‘Definitely would buy’ thresholds had a lower trend. It was postulated that, despite each consumer being instructed to rate packs entirely on their colour without reference to a presumed eating experience, that the lower thresholds for OWP and VSP might reflect either prior experience with pleasing results from less optimal colour or alternatively a poor experience from attractive MAP product.

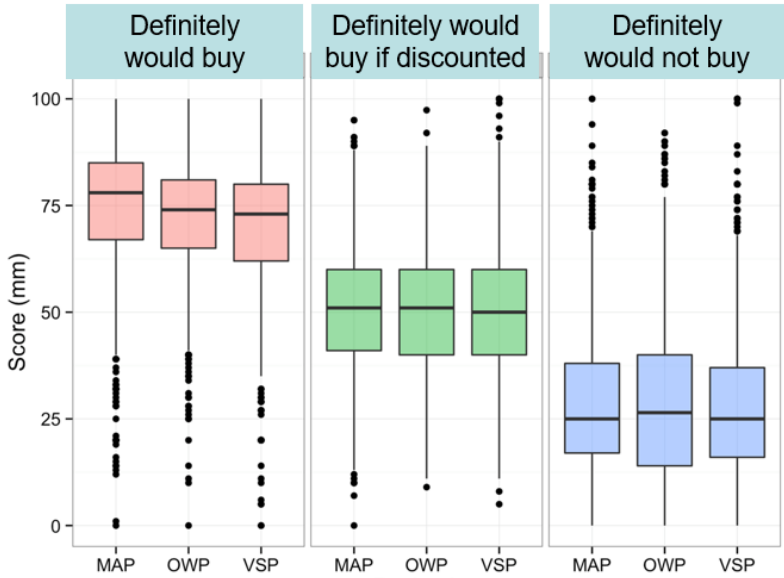


Figure 77. Consumer CMC score relative to purchase intent and packaging type

Fig. 78 presents the relationship between CMC score at 3, 5 and 7 days after retail packaging for MAP and VSP product. It is evident that while the VSP product held constant over the 7 day period the MAP product decreased with the final 7 day CMC similar to the VSP.

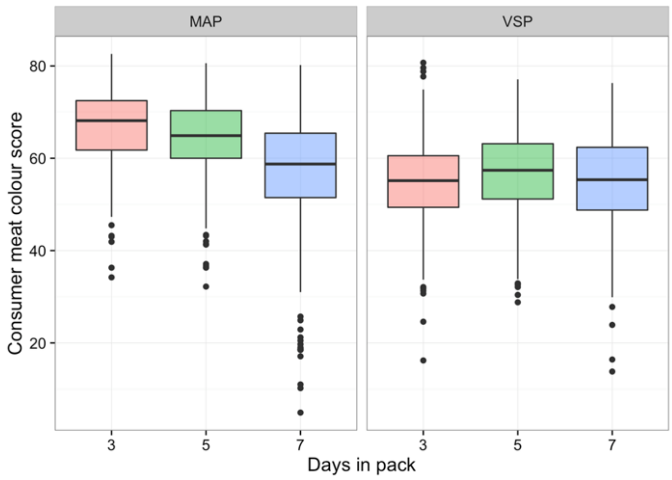


Figure 78. CMC ratings by days in pack during retail display

Fig. 79 presents further detail on the relationship between AMC at grading and CMC ratings of retail packs at 1 (OWP only) and 3, 5 and 7 days (MAP and VSP) post primal fabrication and retail packing. Quadratic lines are fitted for each packaging type in the Fig. 79 plots that relate AMC at grading, boning, pre and post retail to the CMC scores. A similar curvilinear pattern is observed with lesser CMC scores for the lighter 1B and 1C AMC values, higher values for AMC 2, 3 and 4 and a flattening out at AMC 5. The CMC deterioration for MAP product with increased days of retail display is evident.

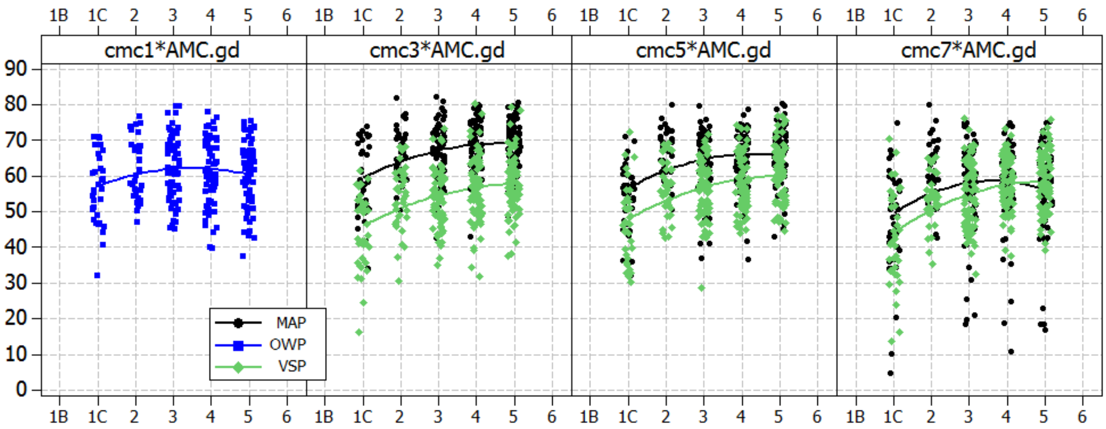


Figure 79. Consumer meat colour score (CMC) in relation to AMC at grading for 1 (OWP only) and 3, 5 and 7 days after retail packing (MAP and VSP).

The mean values for each pack method in relation to days of prior primal ageing, cut and days of retail display are presented in Table 41. As each cell contains 32 observations these data are balanced with the cell means effectively the interaction estimates.

Table 41. Consumer colour score (CMC) means by pack, primal days ageing (horizontal axis), cut and retail display days (vertical axis).

		OWP				MAP				VSP			
		Days of primal ageing pre retail packing											
Cut	Display Day	5	12	40	Av	5	12	40	Av	5	12	40	Av
RMP	1	63.2	56.9	55.5	58.5	*	*	*		*	*	*	
	3	*	*	*		64.6	69.1	66.5	66.8	50.2	51.3	52.9	51.5
	5	*	*	*		60.6	62.6	62.1	61.8	51	58.7	54.5	54.7
	7	*	*	*		57.6	55.4	52.3	55.1	50.8	58	57.7	55.5
	Av	63.2	56.9	55.5	58.5	60.9	62.4	60.3	61.2	50.7	56	55.1	53.9
STR	1	66.7	61.7	59.2	62.5	*	*	*		*	*	*	
	3	*	*	*		66.3	64.7	68.2	66.4	54.6	55.5	58.9	56.3
	5	*	*	*		64.9	67.9	67.9	66.9	54.3	58	53.8	55.3
	7	*	*	*		59.2	60.4	61.4	60.3	55.6	53.6	52.8	54
	Av	66.7	61.7	59.2	62.5	63.5	64.4	65.8	64.6	54.8	55.7	55.2	55.2
TDR	1	66.5	60	59.4	61.9	*	*	*		*	*	*	
	3	*	*	*		64.4	67.9	69.9	67.4	56.5	52.9	58.5	56
	5	*	*	*		65.6	63.5	61.6	63.6	59.2	62.7	59.2	60.4
	7	*	*	*		61	54.9	46.9	54.3	54.4	51.4	58.8	54.9
	Av	66.5	60	59.4	61.9	63.7	62.1	59.4	61.7	56.7	55.6	58.9	57.1

While the VSP values were similar across both days of prior primal ageing and days of retail display the MAP values were found to significantly decline as retail pack days increased to a point where the less stable rump and tenderloin MAP scores were substantially below the VSP when packed after 40 days of primal ageing. An analysis of variance for CMC reduced to a final model of cut*days in retail pack prior primal aged days for each cut found retail pack days and the cut*retail pack days interaction to be significant for MAP (P>0.01), cut, cut*retail pack days and primal days aged significant (P>0.01) for VSP with cut and primal days aged significant for OWP (P>0.01) which was only displayed for 1 day.

The visual consumer CMC relationships were also reflected in the AMC values assigned by the MSA grader immediately prior to and post the retail pack periods for each primal ageing as displayed in Fig. 80.

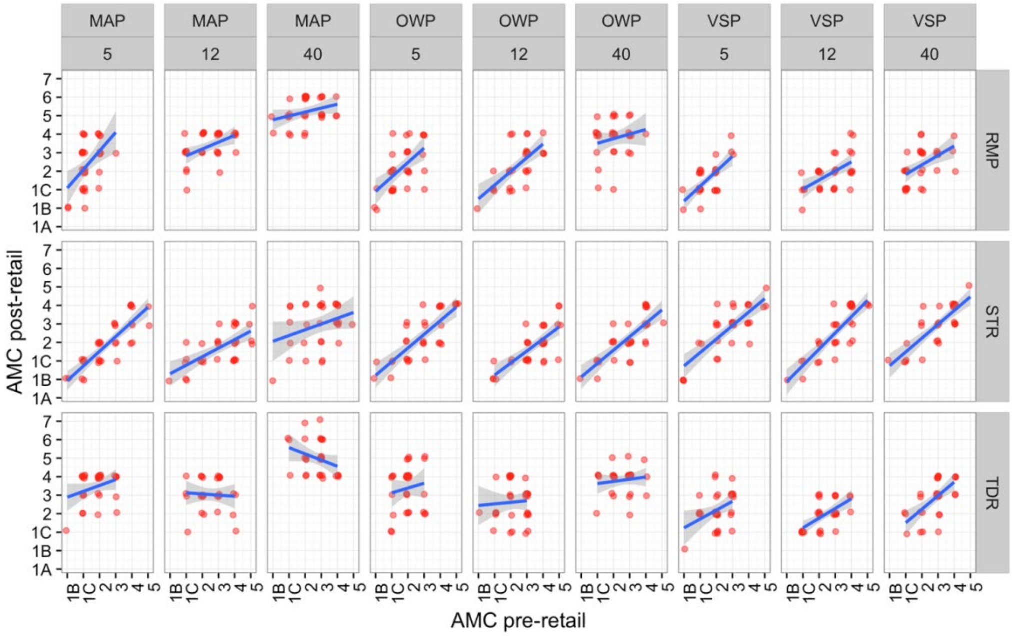


Figure 80. MSA grader AMC scores pre- and post-retail display by pack and days aged

Again, the relative stability of the VSP across cuts at all time periods contrasted with the deteriorating relationship evident in the MAP with increased days of primal ageing and increased retail display days. The OWP scores were also less stable for tenderloin and for rump and striploin after 12, and particularly 40, days of primal ageing.

Cabinet position is often discussed as an important purchase driver of retail sales and routinely used to feature special offers and retail promotions. In relation to meat colour, the impact of uniform and attractive colour is also often held to be important with any pack of different colour to adjacent packs regarded as likely to reduce merchandising impact. To ensure that the project evaluation was as fair as possible the trial protocols attempted to balance out these effects by displaying packs in an 8 x 8 Latin square sequence reflecting colour at grading and pH criteria within each cut and packaging type. Further protocol steps included displaying MAP and VSP product in separate "blocks" on a single cabinet side. The sides were rotated together with shelf and front or rear of shelf for each viewing day. As OWP product was displayed alone and for only one day in each ageing period the rotation related to cut and Latin square set across the 3 ageing periods.

An analysis of variance was run incorporating pack type, cut, days on shelf, shelf and position (front, back and left, right or centre) and days aged was run. While all terms were significant (P>0.000 and P>0.002) other than days aged the numerical differences were slight and the practical consequences limited in regard to position with the largest estimates related to packaging type. The analysis suggests that consumers give better ratings at the extremes of the display (top & bottom shelves, far left and far right). However, these differences are small and of doubtful consequence reflecting the mean shelf CMC scores displayed in Table 42.

Table 42. Average CMC for retail cabinet shelf and position

Shelf	Average CMC	Position	Average CMC
1	61	Front	59.6
2	58	Back	60.2
3	59		
4	57		
5	59		

It should be noted that the retail cabinet used was new and of high quality with LED shelf lighting. As such it was considered to have superior and more uniform lighting conditions than many commercial installations. Consumers were also directed to specific sets of 8 packs in nominated shelf positions ensuring that they would be viewed. While this resulted in the desired assessment of retail colour it should not be interpreted that shelf position has no influence on purchase behaviour. This was not tested within this project and is subject to many influences including line of immediate sight and merchandising cues.

4.3.4.5. Relationships between eating quality, meat colour and packaging system

Consumer sensory testing data was analysed in conjunction with the consumer responses to colour and AMC at boning and grading. MSA grill protocols were used with consumers from Wagga Wagga and Melbourne participating in the sensory tests.

Data analysis found no relationship between consumer rated eating quality (MQ4) and consumer meat colour (CMC) scores, nor between eating quality and AMC at grading. This is illustrated in Figs. 81 and 82 below.

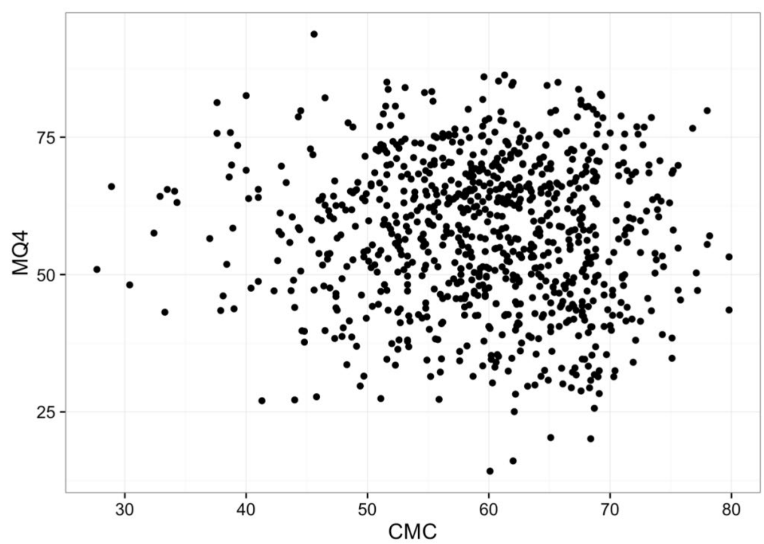


Figure 81. Consumer MQ4 sensory score relative to consumer CMC visual meat colour score

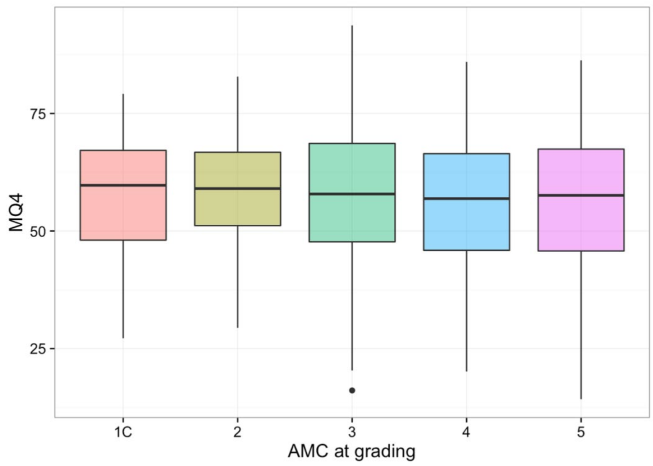


Figure 82. Consumer MQ4 score relative to AMC at grading

In contrast to colour, the relationship of eating quality to packaging type was highly significant with MAP MQ4 (Meat Quality 4 variables – Tenderness, Juiciness, Flavour and Overall Liking) scores substantially below those for OWP and VSP as illustrated in Fig 83.

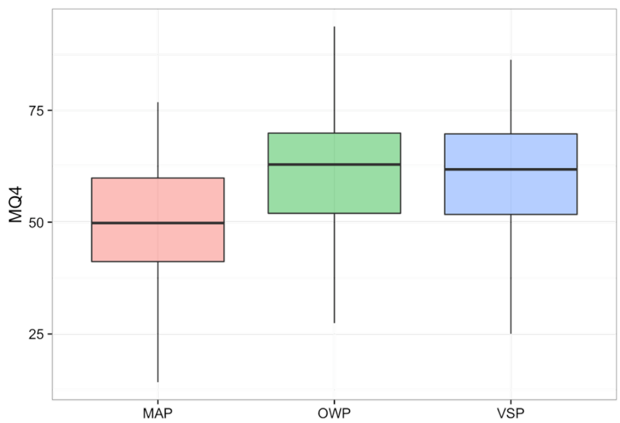


Figure 83. Eating quality (MQ4) scores by packaging system

The same distinct pattern was evident within cut as illustrated by Fig. 84 with a similar result observed within each of the three primal ageing periods as shown in Fig. 85.

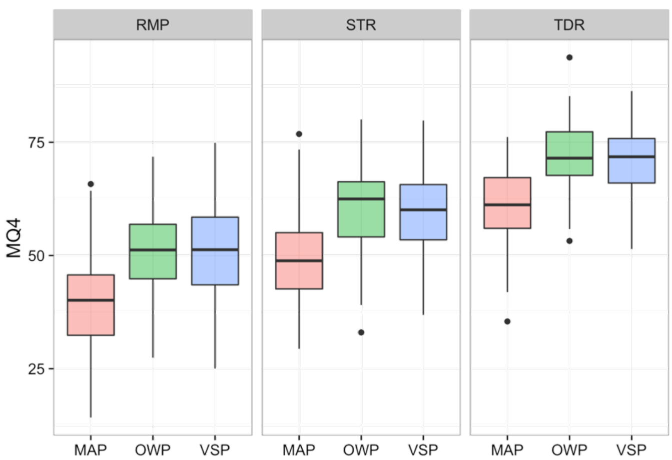


Figure 84. Eating quality (MQ4) scores by packaging and cut

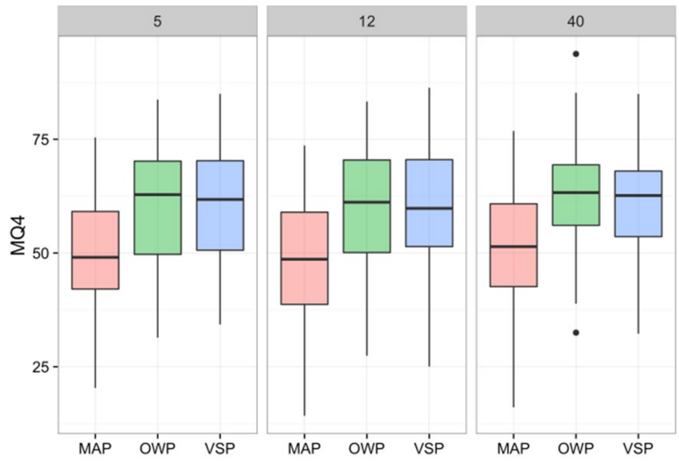


Figure 85. Packaging and MQ4 by prior primal days aged

The consistency of the MAP effect across cuts and ageing days indicated that it was a straight packaging effect rather than an interaction as further illustrated by Fig. 86 which displays a consistent negative pattern across each cut by ageing cell.

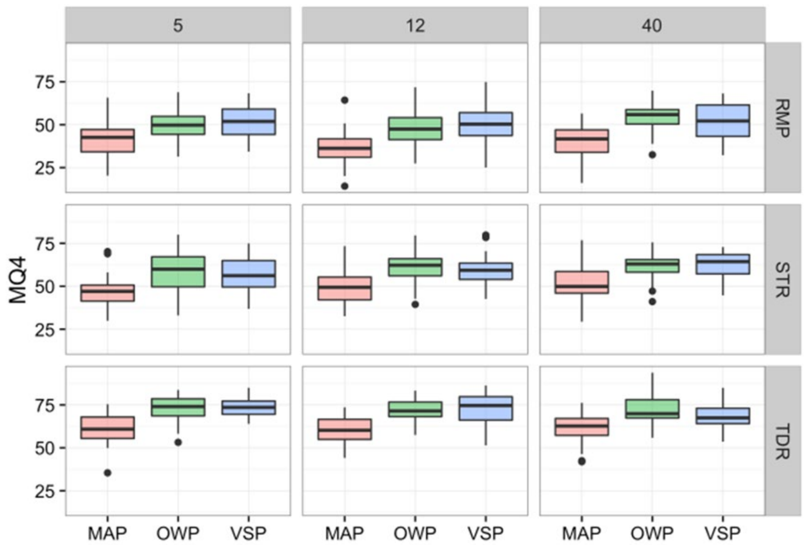


Figure 86. MQ4 score by packaging system, cut and prior days of primal ageing

A number of analysis approaches were tested to confirm and cross check the magnitude of the detrimental MAP effect on MQ4. These included animal based models using all cuts, animal based using separate cuts and a covariate based model using separate cuts. The cut (muscle) and days aged estimates aligned in general with the MSA model estimates, with the animal effects also within an expected range. The large packaging effect, driven by the strongly negative MAP estimate, was of concern and not included in model estimates. The alternative modelling approaches resulted in very similar packaging estimates of a 10 to 12 MQ4 point negative MAP effect.

The analyses were considered by the MSA Pathways Committee which recommended that a 12 MQ4 point penalty be applied to all cuts packed in 80:20 O2:CO2 gas mix. This recommendation was presented to the MSA Taskforce which endorsed the recommendation but elected to delay implementation to allow time for transition and potential further research that might address the problem. Two lines of research were proposed: a study to determine the effect development over the packaging period and changing the gas mix to 40:30:30 Nitrogen:Oxygen:Carbon Dioxide.

Analysis of HunterLab colour readings and limited NIXPro data was not encouraging in relation to predicting consumer CMC score by instrumental means. This finding added to earlier studies by Dr Ray Watson in which HunterLab output was examined in relation to the AUS-MEAT colour chips. His analysis indicated that there was significant variation in chips between plants/day/chip sets. Dr Watson concluded that a score, Meat Red (MR) which is the average red wavelength (600 to 720) intensity, could be useful if the equipment had greater consistency. He presented data demonstrating that the current chips were not uniform in their progression with two serious anomalies between the 1C and 2 chips and between the 4 and 5 chips. He proposed a relationship of L* and chroma weighted 2:1 toward L* that could provide effective separation of the standard chips. Analysis by Dr Garth Tarr evaluating the HunterLab wavelength and L*a*b* readings relative to consumer CMC scores indicated that consumer assessment was not fully explainable by pure colour measures but incorporated “something extra and not defined”.

A sub-set of 122 samples from the packaging study were submitted to AFBI (Dr Linda Farmer) in Belfast for flavour chemistry evaluation. Differences between muscles and ageing periods were significant for a few volatile (odour) compounds, while those caused by packaging and cooking were more extensive including a number of very highly significant differences in volatile compounds, a relevant example being the pentanal difference illustrated in Fig. 87 and the lowering of Strecker aldehydes shown in Fig. 88.

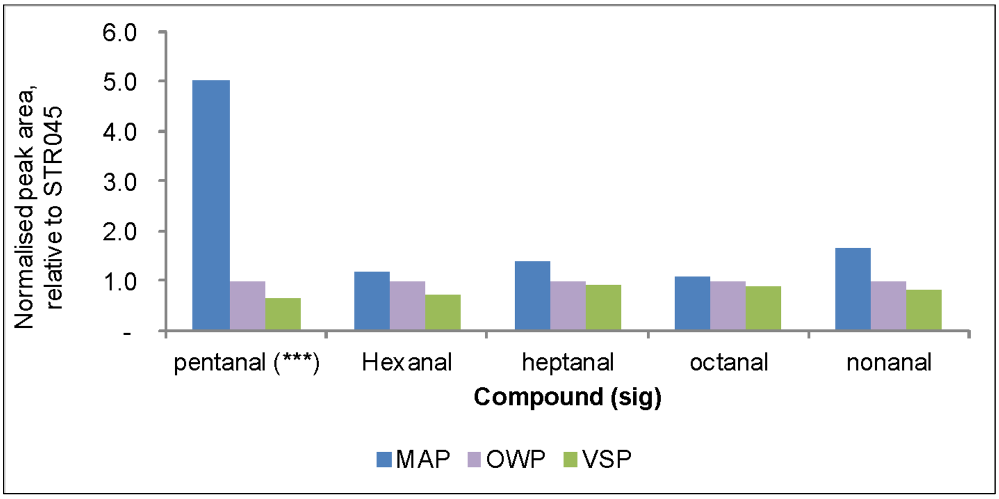


Figure 87. Effect of packaging on n-aldehydes (average of 4 muscles and 3 ageing periods shown relative to overwrap (OWP) = 1

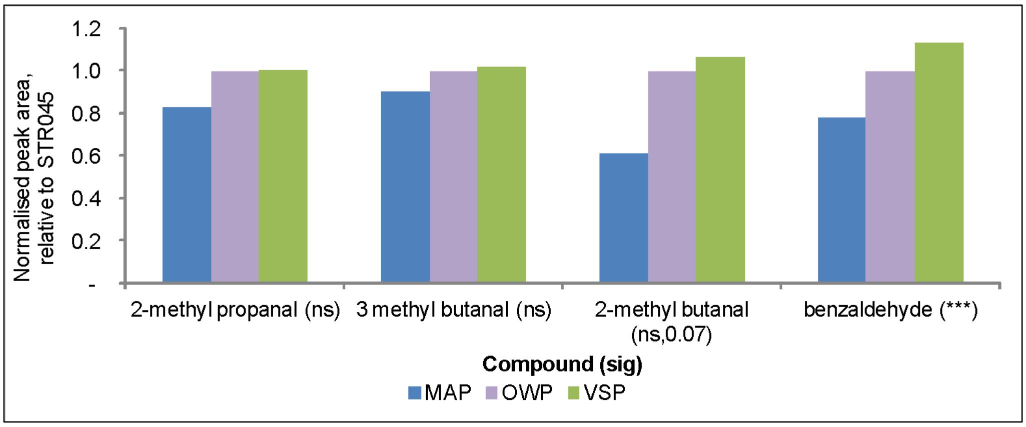


Figure 88. Effect of packaging on Strecker aldehydes (average of four muscles and three ageing periods, shown relative to OWP=1)

The flavour chemistry data indicated that flavour could be altered by packaging processes and that the volatile compounds could act as marker compounds to indicate the changes occurring. This also indicated the potential to utilise them as marker compounds for consumer flavour liking. While there were fewer differences between overwrapped and vacuum-packed beef the vacuum-packed samples had significantly lower concentrations of two ketones, an alcohol and a furan. Further investigation is needed to understand why these compounds alone showed this effect, but all were likely to be formed via oxidation pathways. A recommendation to conduct analyses of flavour precursors to determine whether the changes in volatile compounds could be related to changes in the composition of the meat was made by Dr Farmer.

The study provided a new understanding of factors affecting the formation of groups of flavour compounds in cooked beef. This evidence enabled new processing methods to be proposed to remedy flavour deficiencies and manage flavour formation in commercial beef products. This observation had particular relevance to prospective value adding approaches and was fundamental to the investigation of clean label enhancement potential in further project work.

4.3.4.6. The science of meat colour. Industry briefing by Professor Melvin Hunt

Given the industry conjecture regarding meat colour, and inherent conflict between producer and retailer perspectives, with processors under pressure from both, further consultation was conducted to better understand the fundamental principles involved. A meeting was held with Professor Melvin Hunt, a renowned leading global expert on meat colour and colour chemistry, at Kansas State University to gain his insights.

It was then arranged to bring Professor Hunt to Australia where he presented an industry seminar on meat colour chemistry at head office in Brisbane. He also visited several plants where he delivered further seminars and extensively observed plant procedures and product.

These consultations were extremely valuable in firstly identifying the cause and suggesting a procedure modification to rectify it and, more importantly, building technical understanding and a strong repour with plant staff. This has led to intermittent contact regarding individual colour related trouble shooting and a trusted and expert knowledge source.

4.3.5 Alternative packaging system evaluation

This work, conducted within L.EQT.1813, confirmed and expanded on packaging system outcomes reported in the earlier study. Valid questions raised from the prior study related to potential interactions due to inclusion of non MSA bodies and the absence of grain fed product in the material tested. This project utilised cube rolls and striploins from a balanced mix of grain and grass fed MSA graded cattle, at 3 quality levels from base to high end MSA categories. A supplementary appraisal of each packaging type was conducted using commercial mince.

Sensory samples were tested as grills after visual appraisal on each day, rather than just after the final viewing, to investigate the possible interaction of days in packaging with sensory response. The 80:20 oxygen: carbon dioxide gas mix (MAP) and vacuum skin pack (VSP) packaging systems replicated those utilised in the first study with the original overwrap (OWP) treatment replaced by two alternative gas mixes, TRIGAS (TRI) treatment with 40% Oxygen, 30% Nitrogen and 30% Carbon Dioxide and a high Nitrogen (NIT) treatment with 80% Nitrogen and 20% Carbon Dioxide gas mix. Both the additional treatments had been advocated by parties in Europe and could potentially provide a low cost transition from conventional high oxygen MAP as no change was required in packaging machinery.

The consumer meat colour (CMC) score statistic developed and utilised in P.PIP.0488 was again used to record consumer ratings of visual appeal and to define cut-off points that effectively assigned retail packaged product to “would definitely buy”, “would definitely buy if discounted” or “would definitely not buy” categories. There were clear and significant differences between the packaging treatments as displayed in Fig. 89.

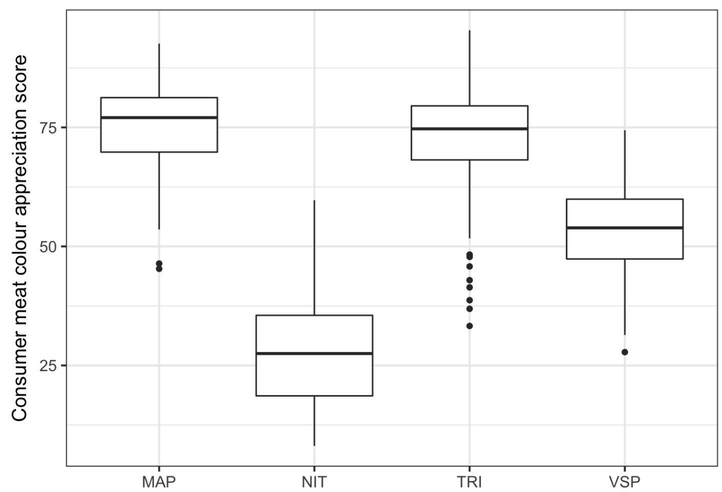


Figure 89. Distribution of Consumer Meat Colour (CMC) score by packaging type

Clearly both the MAP and TRI packaging with 80% and 30% oxygen respectively provided a superior CMC value whereas NIT packaging was scored substantially lower and VSP intermediate. Results of a linear mixed model by REML of CMC related to pack and days in pack produced contrast values displayed in Table 43.

Table 43: Contrast estimates and standard error for CMC and Packaging Types

Contrast	Est CMC	se
NIT-TRI	-43.75	1.9
NIT-VSP	-25.7	1.19
MAP-TRI	2.78	1.18
TRI-VSP	18.05	1.19
MAP-VSP	20.83	1.19
MAP-NIT	46.53	1.19

When examined at a more detailed cut and position level, as demonstrated by Fig. 90, it is clear that the packaging effects are relatively uniform across cuts and position within cut. Analysis indicated significance (P<0.001) for packaging type and the interaction of packaging type and days in pack.

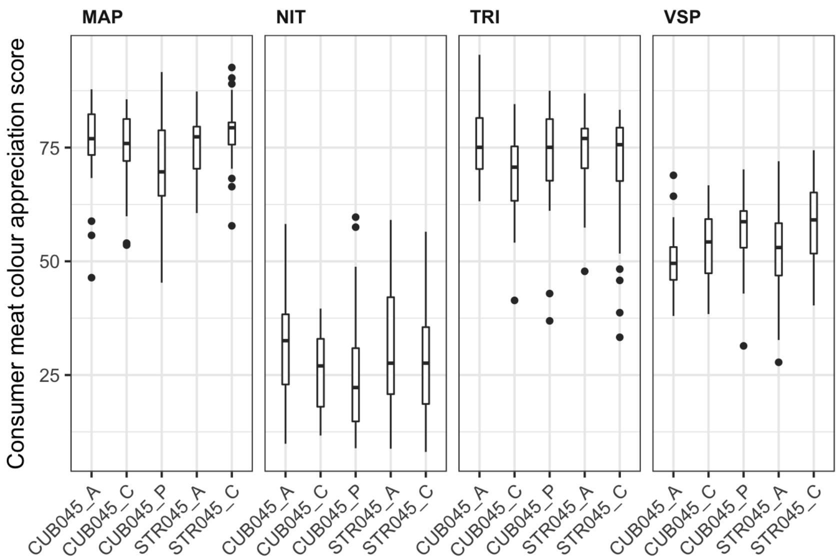


Figure 90. Distribution of CMC scores by cut position within packaging type

These contrasts were also reflected in the allocation to purchase intent categories displayed in the violin plots in Fig. 91 for steak and mince. Both were remarkably consistent and very close to the previous project CMC cut-offs. A linear discriminate analysis produced classification cut-offs of 58.4 and 33.9 with a corresponding overall in-sample prediction accuracy of 81.2% whereas a classification and discriminate regression tree approach yielded cut-off values of 60.5 and 30.5 with accuracy of 82.2%**.**

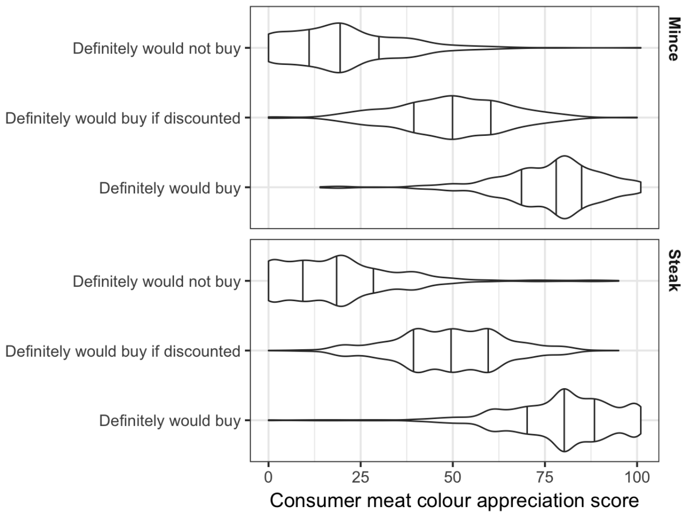


Figure 91. Distribution of consumer meat colour (CMC) scores for retail packs of mince and steak by purchase intent. The three vertical lines in each violin plot indicate the first quartile, median and third quartile respectively.

The relationship between CMC and AUS-MEAT meat colour measured during MSA grading was less than convincing, as depicted in Fig. 92 and in more detail in Fig. 93 where, while clear CMC differences were evident across each of the packaging types and retail viewing dates, there was little relationship or trend in regard to the AUS-MEAT meat colour scores. This aligned with the previous study and highlighted the disconnect of extensive Industry inclusion of AUS-MEAT colour scores in purchase criteria.

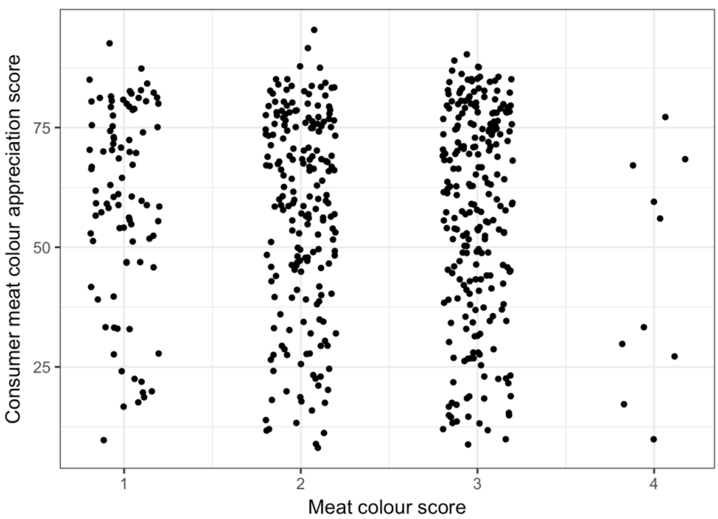


Figure 92. Relationship of CMC score to AUS-MEAT Meat Colour score at grading

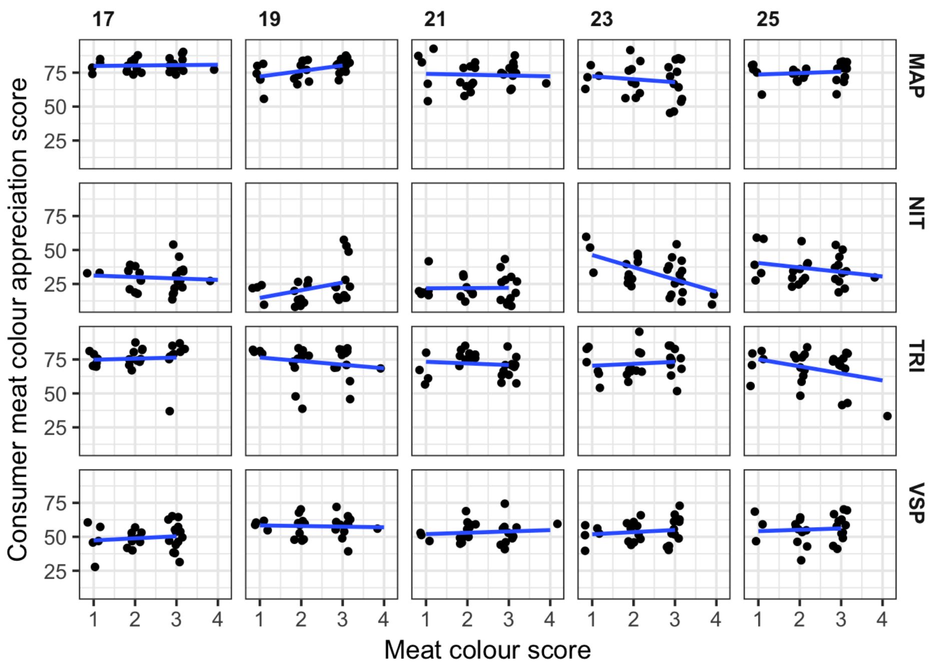


Figure 93. Relationship of CMC to AUS-MEAT Meat Colour at grading by packaging type and display date (Note headings include 16 days of primal ageing prior to retail packing)

The distribution of eating quality MQ4 values by packaging type over the display period are illustrated in Fig. 94. In contrast to the CMC visual appeal scores the MAP and TRI treatments are significantly (P<0.001) lower than the NIT and VSP. Relative to VSP the MAP treatment predicted MQ4 mean is -6.32, TRI -4.04 and NIT -0.98. The detrimental MAP effect was reduced relative to the prior P.PIP 0488 2015 trial but approached a similar negative position by day 9 with the results for both experiments within the confidence interval.

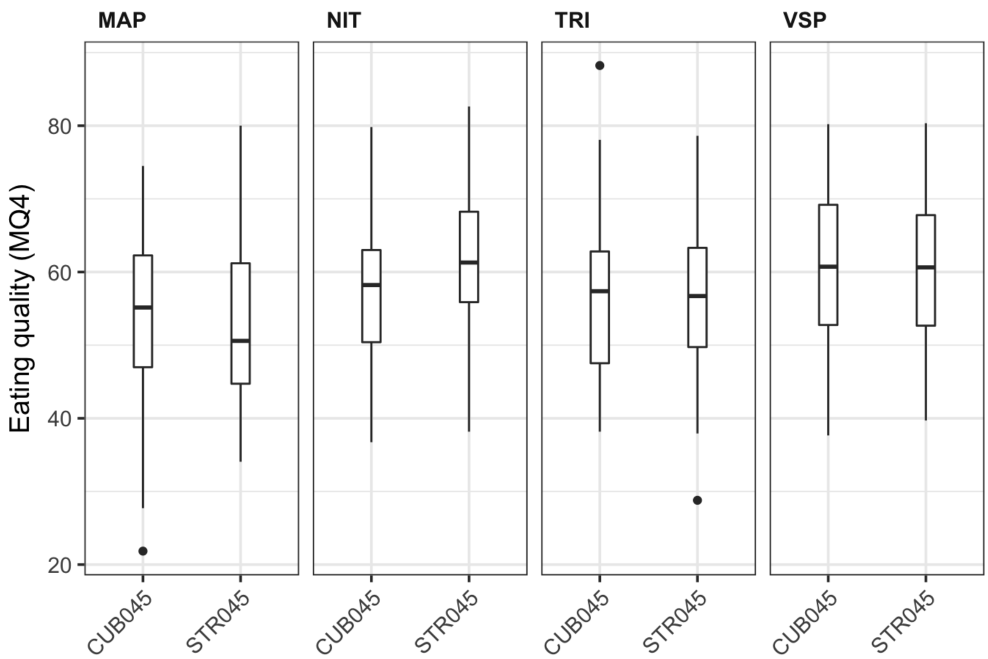


Figure 94. Distribution of MQ4 score by cut within packaging type

When analysed using a linear model and treating days in retail pack as a categorical value days in pack failed to reach significance ($P<0.05$) across all packaging types. The predicted mean values for each packaging type at the 5 retail pack display periods are shown in Table 44 and graphically in Fig. 95. There were different trends, although not reaching statistical significance. The MAP and TRI-GAS declined with increased days of display with the difference between them reducing with time, the NIT increased and the VSP effectively remained stable, a pattern not dissimilar to the meat colour acceptance observations.

Table 44. Adjusted mean MQ4 values for packaging type and display period

PACKAGING	DISPLAY PERIOD (DAYS)				
	1	3	5	7	9
VSP	60.9	60.6	60.2	59.8	59.5
NIT	57.8	58.5	59.1	59.8	60.5
TRI-GAS	58.2	57.1	56.1	55.1	54.1
MAP	55.1	54.5	53.8	53.2	52.6

While slightly reduced the TRI-GAS treatment paralleled the MAP effect in magnitude and pattern over time. The NIT treatment appears to trend upward over time with the VSP trending slightly lower.

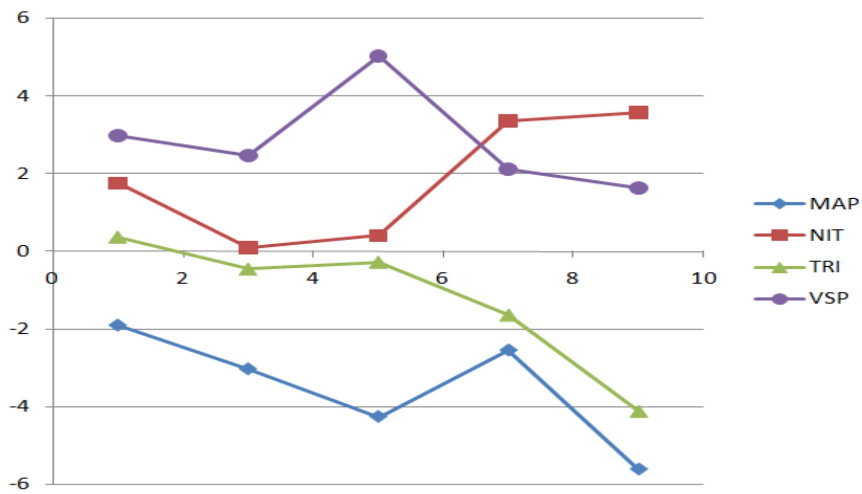


Figure 95. Adjusted MQ4 differences between packaging types across a 9 day period

Despite differences in cattle type, dentition and pH, primal ageing, muscles tested and days of display the packaging effects were statistically similar for both this and the previous study reported in P.PIP.0488 with overlapping confidence intervals.

Further analysis was conducted to investigate possible HGP and marbling interactions with packaging. The tested product was obtained from 54 British breed steer carcasses which differed significantly in eating quality ($P<0.001$). The carcasses comprised 20/34 from No HGP/HGP implanted cattle. Previous work suggested that retail packs using high O2 MAP resulted in tougher meat. The literature suggested that this toughening may have been caused by a number of different mechanisms including deactivation of the calpain/calpastatin enzymes and crosslinking of myosin heavy chain proteins through disulfide bonding (Geesink et al 2015). The recent paper by Polkinghorne et al (2018) discounted the deactivation of the calpain/calpstatin system as a contributing factor to the high O2 MAP effect as the effect was similar in muscles that aged at different rates (tenderloin, rump and striploin) and were aged in the bag for different times (5, 12 or 40 days before being placed in retail packs).

Including HGP and the interaction between HGP and treatment in the mixed model effectively provided a further test of whether the high O2 MAP effect interacted with HGP effects. As expected, the HGP effect was significant (HGP treated carcasses were tougher, $P<0.05$), but there was no interaction between the treatment x HGP interaction. This supported the results of Polkinghorne et al (2018) that higher calpastatin in the HGP treated carcasses did not interact with the magnitude of the high O2 MAP effect.

The fourfold range in marbling scores in the 54 carcasses provided an opportunity to test if marbling interacted with packaging treatments. As expected, whilst marbling had a large effect on sensory scores the interaction between marbling score and treatment was not significant ($P>0.05$).

The results for each aspect of the project were definitive for both visual and sensory evaluation when cooked. The primary comparison of MAP and VSP also aligned with the prior P.PIP.0488 outcomes with close to identical boundaries for consumer colour score thresholds. Differences between 80:20 high oxygen MAP and VSP were marginally lower than in the earlier study but did not differ statistically. The negative MAP deduction was statistically significant from day 1 after retail packing with a trend to increase over time to day 9 due to deterioration in MAP and TRI scores.

The final MSA Pathways recommendation of an 8 MQ4 point deduction reflected these findings.

The significant discount of MAP and TRI found in the steak results were amplified in the mince analysis as depicted in Fig. 96. The VSP and NIT results also displayed a pattern common to the steak data with both significantly above the high oxygen treatments and NIT tending to increase with days in pack and VSP to marginally decrease.

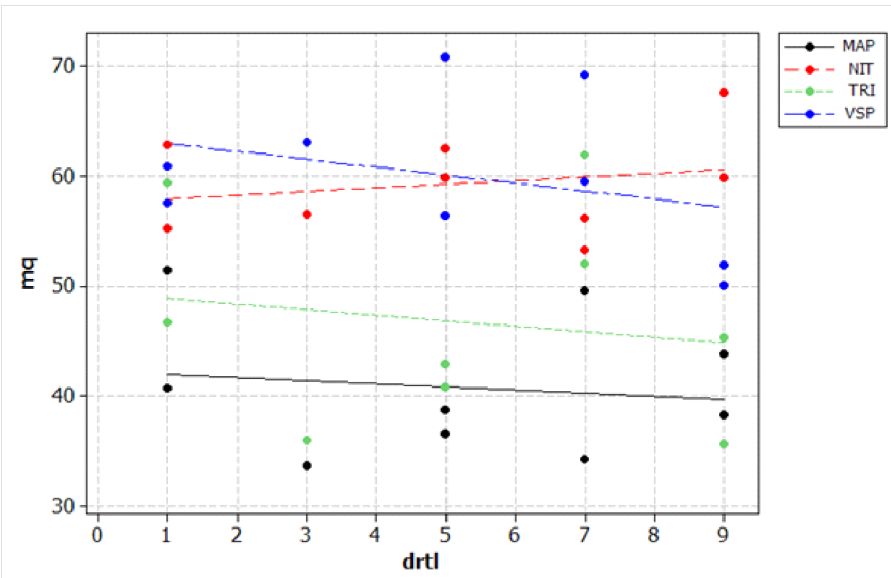


Figure 96. MQ4 relative to days in retail packaging for VSP, NIT, TRI and MAP retail packs

The concerning difference however was that the MAP discount was estimated to be in the order of 20 MQ4 points, threefold that observed in the steak packs. While there were lower numbers of mince packages the consistent pattern of the results suggests they are realistic.

Given the large proportion of supermarket mince sales in MAP packaging further urgent work was recommended to further evaluate the scale of the effect across a larger sample size.

4.3.6. Long term ageing in Thermoform

An extensive study to evaluate extended ageing in Thermoform packaging was initiated due to its' relevance to the China market. Direct Thermoform packing in the boning room provided significant advantages in more direct B2C supply of chilled rather than frozen product but carried attendant risk that eating quality might decline over the extended 120 day period desired. These concerns were amplified due to the proposed cuts, several of which (rib fingers, shin) had small mass and proportionally large surface area, thought to carry a greater risk of deterioration and consequent reduced shelf life.

China eligible product was collected with selected "China" cuts Thermoform portioned, individually identified and packed in the boning rooms. The individual packs were then aged at CSU with packs sequentially removed at 7 day intervals between 21 and 140 days post kill, fabricated into MSA protocol grill or stir-fry samples and frozen prior to sensory testing, also following MSA protocol. The majority of these samples have been MSA tested with results to be utilised in ageing estimates within future MSA model upgrades.

Prospective striploin ageing curves for MQ4, tenderness and flavour produced by Prof Ray Watson are displayed in the Fig. 97 raw data scatterplots. The red curve is a fitted quadratic—as a guide rather than anything definitive; and the blue dotted curve is a smoother. The plots in the left column have restricted scale (52 to 62) so that the shape of the fitted curves are clearer. The plots are the same, only the scales are different. Of course, many of the data points are off the plot for the restricted range plots.

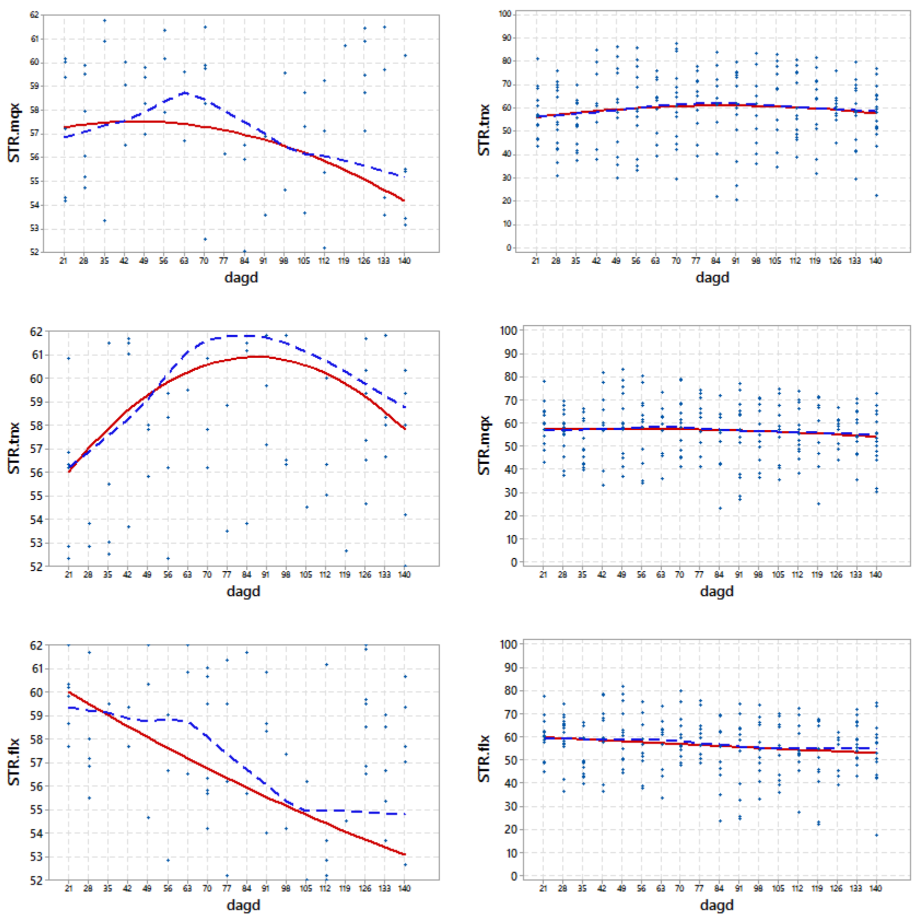


Figure 97. Raw data scatter plots of striploin ageing from 21 to 140 days in Thermoform

From Fig. 98 it is seen that the MQ4 score of the striploin peaks around 70 days of ageing then declines. On closer observation this decline is principally related to flavour change, a pattern that has been observed with other long aged product packed in the USA and over a short period for high oxygen MAP. This supports the need to better understand flavour development and precursors in order to either prevent deterioration by alternative management practice or other interventions.

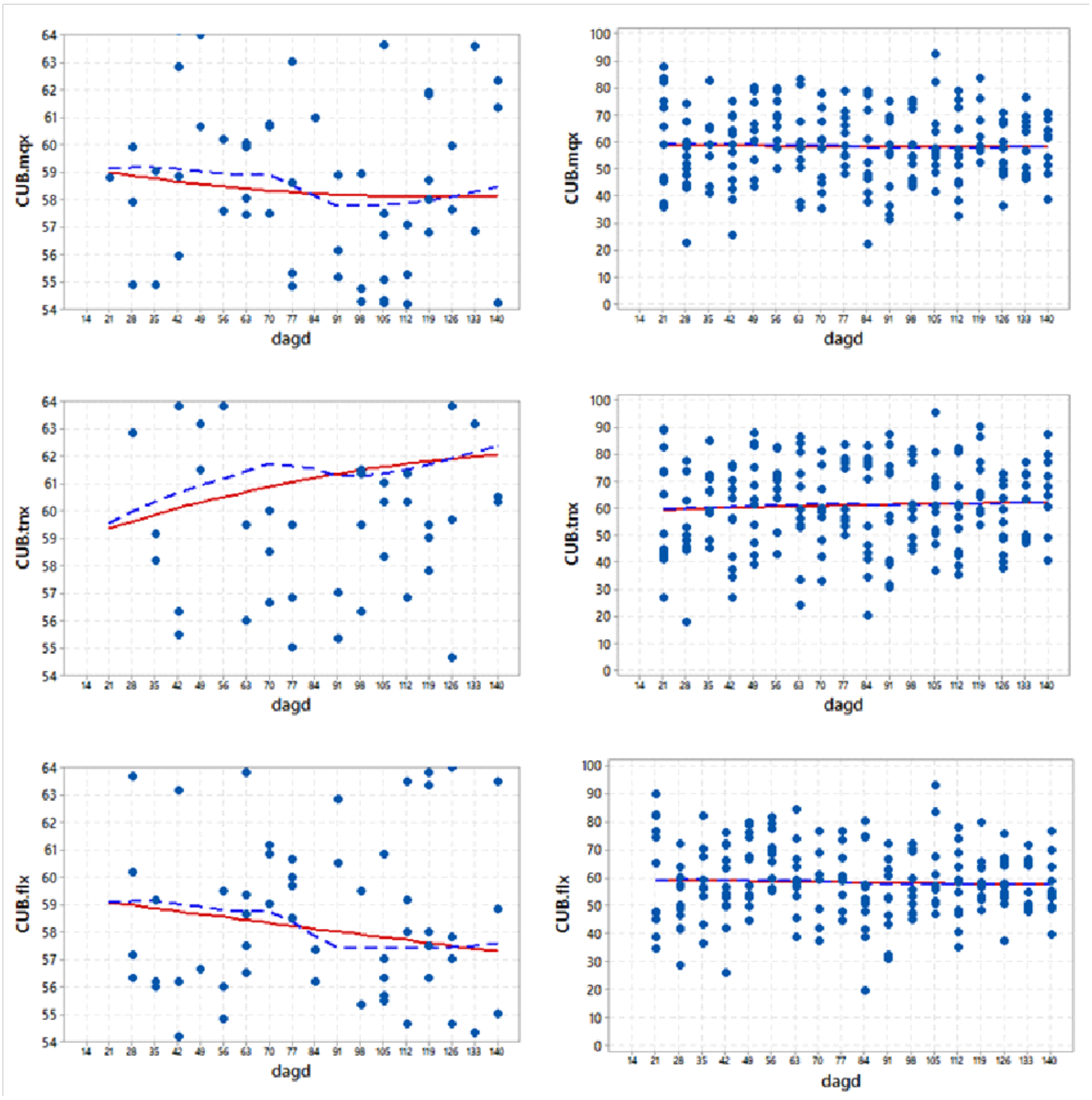


Figure 98. Raw data scatter plots of cube roll ageing from 21 to 140 days in Thermoform

The cube roll results, presented in Fig. 98 are similar to those of striploin which might be expected. The chuck results displayed in Fig. 99 also suggest a similar response which Ray observed as "The smoother suggests a familiar theme: MQ is slightly reduced: tenderness increases a bit and flavour decreases somewhat—around dagd=50".

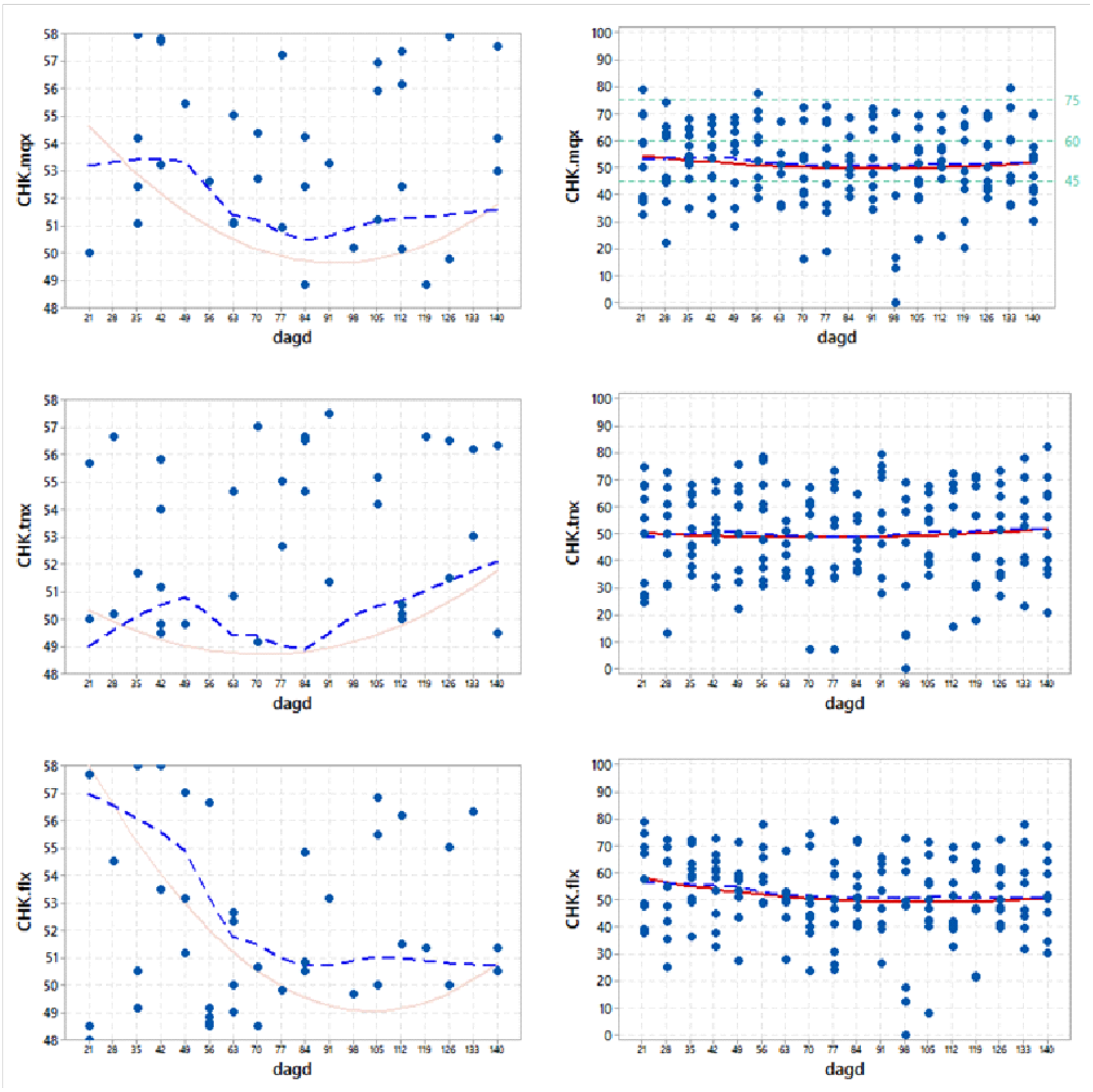


Figure 99. Raw data scatter plots of chuck roll ageing from 21 to 140 days in Thermoform

Professor Watson also utilised a model to adjust for animal effects across the cuts tested as by design the source animals varied considerably with a common collection, ageing and consumer testing pattern applied to all. He reported the estimated animal effects for these data were mostly between –10 and +10, with some as large as 20 as illustrated in Fig. 100.

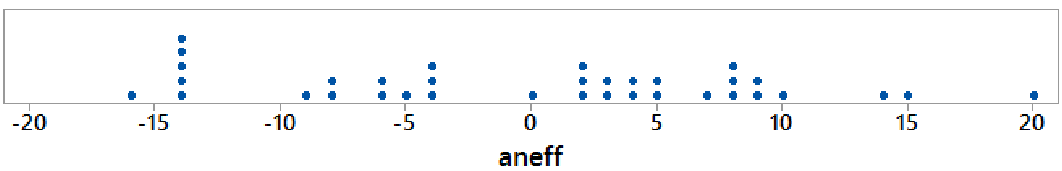


Figure 100. Predicted animal effects for Thermoform cut collections.

The adjusted means for Thermoform aged striploin samples are presented in Fig. 101. To quote Prof Watson "The message here is much the same as that obtained from the raw data: tenderness increases to around dagd=60 and thereafter stays about the same; flavour is unchanging until around dagd=60, after which it decreases until dagd=100 after which it stays at about the same level. MQ4 increases with tenderness, then decreases with flavour. The good news is that it seems to reach a fairly stable plateau, which is not much less than where it was at dagd=21". The smoothed cube roll plot also followed a similar trend although more erratic prior to smoothing.

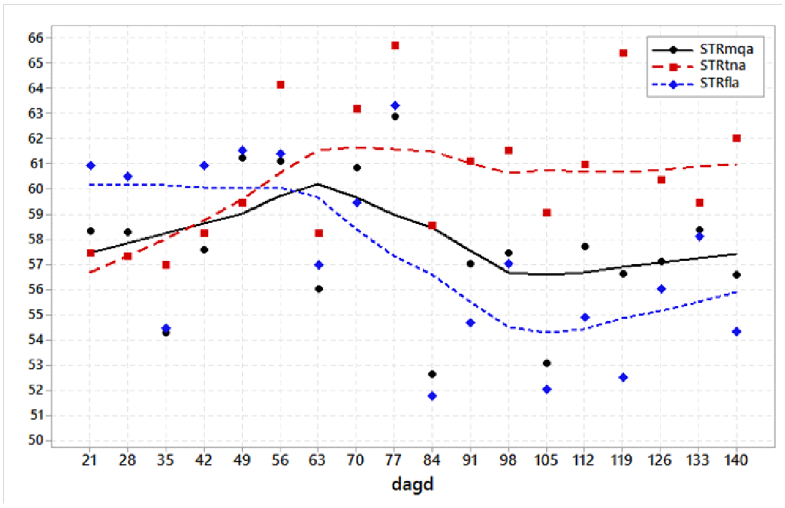


Figure 101. Predicted means for Thermoform aged striploin MQ4, tenderness and flavour scores from 21 to 140 days ageing.

There were fewer data points for the heel muscle due to its size (n=54 over 18 dagd values) making conclusions more tentative but indicating that reasonable MQ remained to 140 days with the later period associated with a decline in flavour after initial improvement to around 60 days as displayed in Fig. 102.

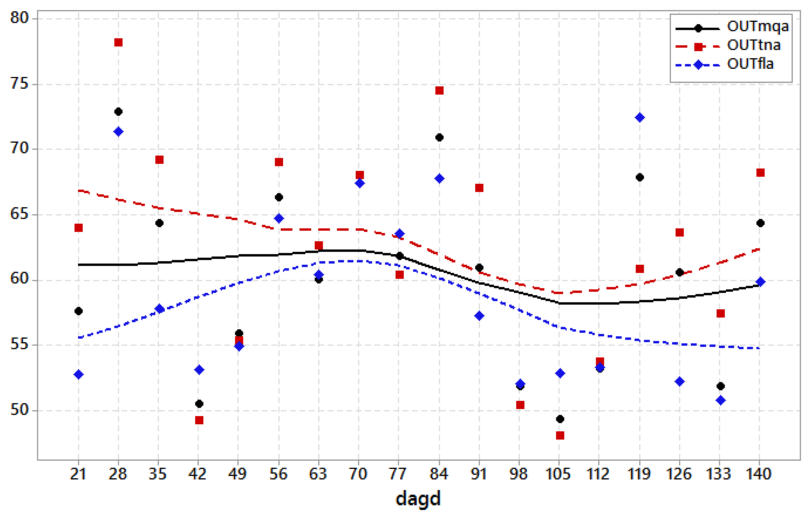


Figure 102. Predicted means for Thermoform aged heel muscle MQ4, tenderness and flavour scores from 21 to 140 days ageing.

The shin special trim group of muscles were pooled for calculation of predicted means as shown in Fig. 103. The ageing effect appeared minor with the upward swing at the end attributed to noise, and an exceptional value at dagd=140.

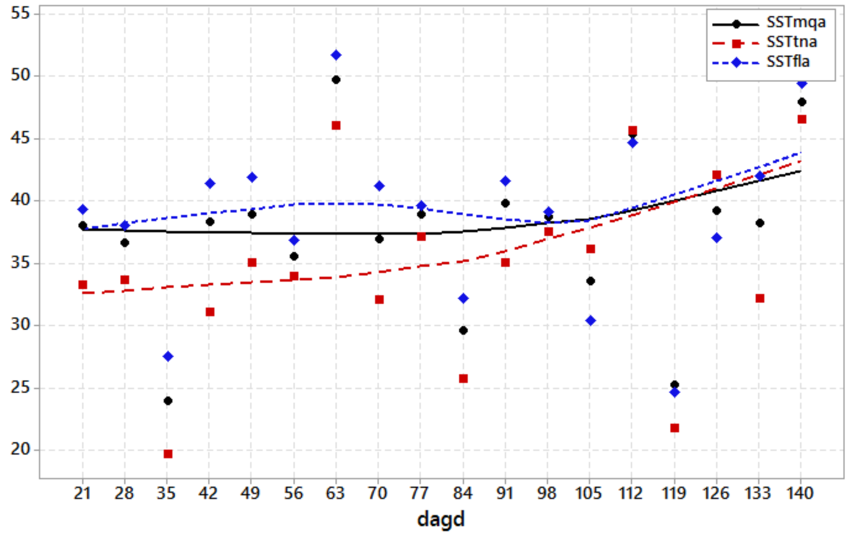


Figure 103. Predicted means for Thermoform aged shin special trim muscles MQ4, tenderness and flavour scores from 21 to 140 days ageing.

The raw scores for each special shin muscle were examined with plots for tenderness in Fig. 104 and for flavour in Fig. 105. Again, little ageing impact was observed across the range for either scale with relatively low scores for the FQ shin and FQS006 muscles in particular.

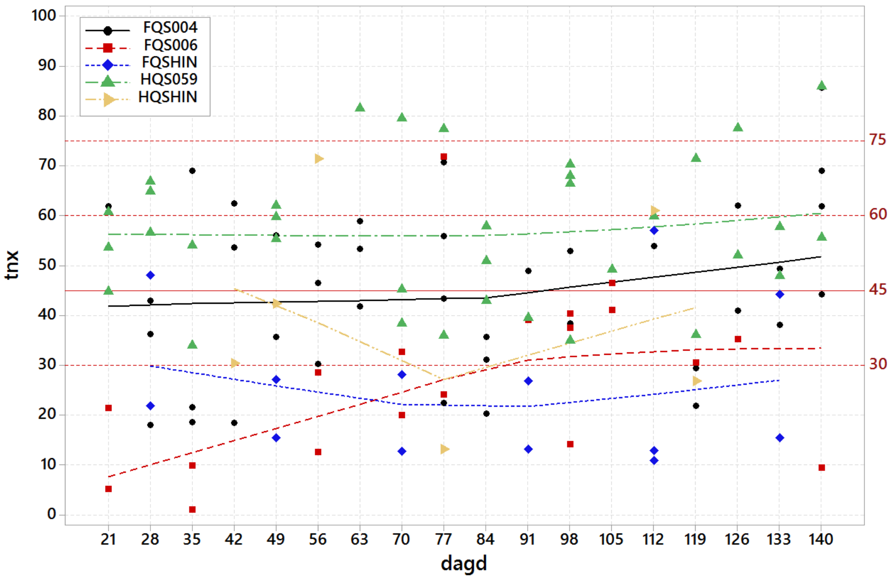


Figure 104. Raw tenderness means for shin special trim muscles aged from 21 to 140 days in Thermoform.

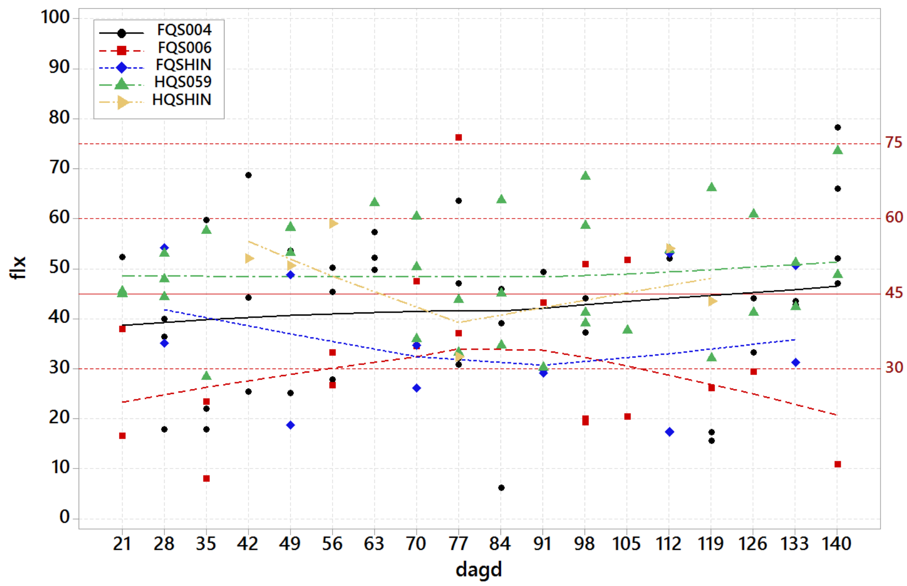


Figure 105. Raw flavour means for shin special trim muscles aged from 21 to 140 days in Thermoform.

While final samples are still to be tested the cuts evaluated aged to 140 days with some deterioration, heavily driven by declining flavour after around 70 days ageing. It should also be noted that a number of samples were discarded due to very strong objectionable odours. For the most part these were leakers that were noticed in the early period and repacked in vacuum bags. Final ageing estimates will be generated by Professor Watson in conjunction with an MSA model revision.

The evidence of flavour deterioration driving a decrease in consumer appreciation with extended ageing and some packaging types deserves further attention in order to better understand the causative factors and provide guidance and potentially commercial interventions to alleviate or reduce the impact.

4.3.7. Briskets and Ribs

The Texas BBQ evaluation of briskets and ribs produced highly significant results of direct commercial value through a transition from largely unsatisfactory to highly acceptable consumer ratings. These studies, encompassing an extensive structured raw material range incorporating Australian and USA product and consumer evaluation, also quantified interactions between muscles, serving style (sliced, chopped and pulled), and between restaurant applicable serving soon after cooking relative to a simulated retail system of re-heating after 7 days of chilled display in vacuum packaging.

Initial analysis by Dr Ray Watson using the model shown in Table 43 indicated that all effects were significant and together accounted for a large proportion of variance with an R^2 of 54.21.

Table 45. Simple model output for TBQ brisket

Source	DF	SS	MS	F	P
PBR	4	6922.3	1730.6	13.84	0.000
Feed	1	632.0	632.0	5.05	0.025
Source	2	2781.6	1390.8	11.12	0.000
Muscle	2	10957.5	5478.7	43.82	0.000
Reheat	1	2652.7	2652.7	21.22	0.000
Form	2	2093.5	1046.7	8.37	0.000
Error	599	74895.0	125.0		
Total	611	163552.3	S = 11.18	**R-Sq = 54.21%**	

The individual trait estimates were:

constant	**57.24**	
PBR		
1.manufacturing	-11.53	*45.7*
2.value-add	-1.95	*55.3*
3.select	0.86	*58.1*
4.classic	5.23	*62.5*
5.premium	7.39	*64.6*
Feed		
grain	1.4	*58.6*
grass	-1.4	*55.8*
Source		
Wagga	3.48	*60.7*
Rockhampton	-9.7	*47.5*
Nebraska	6.22	*63.5*
Muscle		
BRI056	-4.89	*52.4*
BRI057	3.99	*61.2*
BRI079	0.9	*58.1*
Direct/Reheat		
direct	2.18	*59.4*
reheated	-2.18	*55.1*
Form		
chopped	1	*58.2*
pulled	-2.73	*54.5*
sliced	1.73	*59*

These relationships were confirmed by further data and analysis; the initial raw material quality (PBR) impacted the consumer rating after cooking, there were differences between the muscles, reheating reduced MQ4 in the order of 4 points and serving in pulled form produced lower results than serving sliced or chopped.

Further statistical analysis by McGilchrist et.al displayed in Table 46 demonstrates that the eating quality (MQ4) differences found within the point end brisket muscles are reflected in each of the sensory traits.

Table 46. Analysis of sensory traits for point end brisket muscles (McGilchrist et.al)

Least Squares means for muscle (*M. pectoralis profundus,* BRI056; and *M. pectoralis superficialis,* BRI057)

CUT	Tenderness	Juiciness	Flavour Liking	Overall Liking	MQ4	Satisfaction
BRI056	69.8^{b}	52.3^{b}	61.1^{b}	62.1^{a}	63.1^{b}	3.3^{b}
BRI057	78.3^{a}	72.9^{a}	65.6^{a}	69.5^{b}	71.3^{a}	3.6^{a}
SEM (largest)	1.5	1.3	1.2	1.2	1.2	0.04
P-value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

^{ab} Within a column, means sharing a common superscript, do not differ ($P < 0.01$).

Table 47 illustrates that that the serving form also impacted each sensory scale with chopped and sliced forms only differing for flavour and serving in pulled form consistently lower.

Table 47. Effect of serving form on TBQ brisket sensory trait. (McGilchrist et.al)

Estimated difference (± 95 % confidence interval) in Australian and USA consumer sensory scores of tenderness, juiciness, flavour, overall liking and meat quality score (MQ4) for each serve method (Chopped, Pulled and Sliced)

Serve	Tenderness	Juiciness	Flavour	Overall Liking	MQ4
Chopped	64.3 ± 2.38^{a}	55.7 ± 1.87^{c}	61.3 ± 1.24^{c}	60.5 ± 1.58^{c}	61.3 ± 1.65^{e}
Pulled	59.6 ± 2.37^{b}	51.7 ± 1.85^{d}	57.7 ± 1.22^{d}	56.0 ± 1.57^{d}	57.1 ± 1.63^{f}
Sliced	66.9 ± 2.36^{a}	55.9 ± 1.84^{c}	59.3 ± 1.21^{d}	59.1 ± 1.56^{c}	61.1 ± 1.63^{e}

$^{a, b}$ Different superscripts within column denote a difference in the estimated difference between serve method ($P < 0.001$)
$^{c, d}$ Different superscripts within column denote a difference in the estimated difference between serve method ($P < 0.05$)
$^{e, f}$ Different superscripts within column denote a difference in the estimated difference between serve method ($P < 0.01$)

Analysis by Dr Watson indicated that these serving form differences did not interact with the source animal, abattoir, muscle or country in which the product was served. Significant country differences were however noted for the navel end brisket. On examination it was established that the TTU preparation method after cooking differed from that at UNE which was believed to account for the score difference. Further work at TTU compared paired navel end brisket cooked as TBQ relative to that processed as pastrami or an American style corn beef. The TBQ results were consistently higher than either option.

Due to the TBQ cooking method being substantially different to previous cooking methods Dr Watson also examined the consumer sensory scale weightings and cut-offs to determine if the standard MSA weightings of 0.3 Tenderness, 0.1 Juiciness, 0.3 Flavour and 0.3 Overall were appropriate. These analyses, presented in Table 47, followed the established form of discriminate analysis in which alternative analyses were conducted including the 4 sensory scales (SQ4) and a 3 scale (SQ3) comparison omitting overall. This approach provided an understanding of which aspects were driving the overall scale. For explanation the figures in blue at the top of each column are the optimum cut-off scores for these data to segregate Unsatisfactory from 3*, 3* from 4* and 4* from 5*. The numbers below the cut-offs are the weightings that apply to each sensory scale at each cut-off and by definition must sum to 1. Comparison of the weightings within each row indicated trends related to the consumer quality levels.

Table 48. Sensory weightings and cut-off scores for TBQ brisket

SQ4					SQ3					MQ* wts
0.652	44.1	67.7	83.0		0.610	46.2	66.6	82.0		
tn	0.19	0.05	0.07	0.10	tn	0.36	0.16	0.14	0.22	0.16
ju	-0.08	0.19	0.28	0.13	ju	0.03	0.29	0.35	0.22	0.18
fl	0.12	0.20	0.28	0.20	fl	0.61	0.55	0.51	0.56	0.38
ov	0.77	0.56	0.37	0.57						0.28
MQ3133										
0.629	45.0	69.4	84.5							

As shown in Table 48 the SQ4 output indicated that the overall score was the highest but halved as quality level increased as did tenderness, whereas the juiciness and flavour scores increased. When overall was removed (SQ3) the flavour scale dominated, indicating it was the primary contributor to the overall scale, and the same pattern of tenderness becoming less important and juiciness more important noted as product quality increased.

The righthand columns in red indicated the average weighting for each scale across all quality levels with the MQ* to the extreme right the average of the SQ4 and SQ3 values. This value was the optimum MQ4 weightings for these data (MQ4*) and produced a classification rate of 0.634 (the proportion of consumer 2, 3, 4 and 5* ratings correctly predicted from the weightings and cut-offs). This was a measure of consumer consistency and compared to a 0.629 classification accuracy delivered by the standard 0.3, 0.1,0.3, 0.3 MQ4. Given that the standard weighting resulted in very similar accuracy TBQ specific weightings and cut-offs were not considered necessary. In practice each set of consumers would have slightly different MQ4* values and be rounded.

In the primary studies all product was cooked as whole cuts in accordance with industry practice with component muscles separated after cooking for individual comparison. It was observed that cooking time to reach the specified temperatures for wrapping in foil and the final cooked end point were extremely variable and largely unrelated to initial weight. This posed difficulties for any batch manufacturing process where a constant cooking time was desired to streamline the process in contrast to the more artisan approach of monitoring individual pieces. A further comparison was made to compare results when the muscles were separated prior relative to after cooking to establish if this could reduce the cook time variation and to evaluate relative consumer sensory response.

Paired briskets from the same carcasses utilised in the "North South" grassfed flavour evaluation were tested together, with briskets from alternate sides cooked whole or as component muscles. While the navel end briskets were only cooked whole due to the small and thin individual muscle form, they were cooked in conjunction with the related point end briskets which were either cooked whole or as individual muscles. The paired samples from each carcase were evaluated within common picks to reduce potential consumer variation. As depicted in Fig. 106 (MQ4), Fig. 107 (Tenderness) and Fig. 108 (flavour) consumer ratings were superior when the full cut was tested relative to the separated muscles. The pattern was similar for the juiciness and overall sensory scales.

It was concluded that despite achieving a more consistent cook time relationship the traditional approach of cooking the entire cut produced a superior consumer outcome, at least when cooked at identical temperature to a common end point. The possibility of cooking to a common total time through a reduced cook temperature setting was not evaluated.

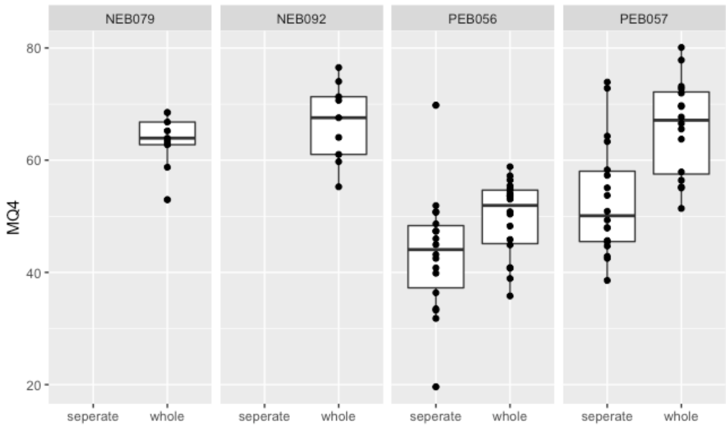


Figure 106. Comparison of consumer ratings (MQ4) for brisket muscles cooked as entire cut or as individual muscles.

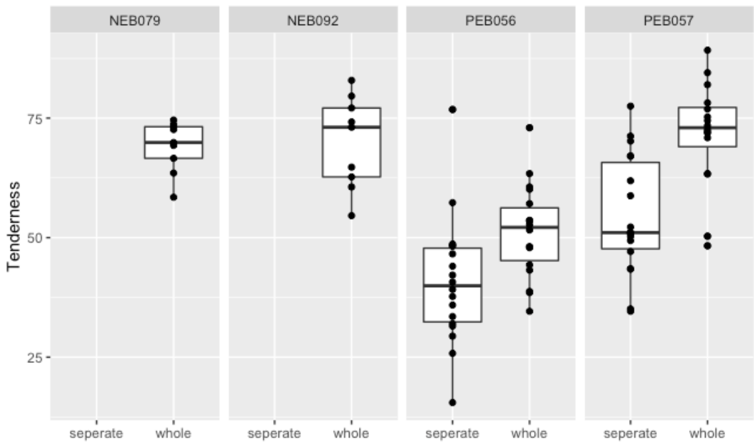


Figure 107. Comparison of consumer tenderness ratings for brisket muscles cooked as entire cut or as individual muscles.

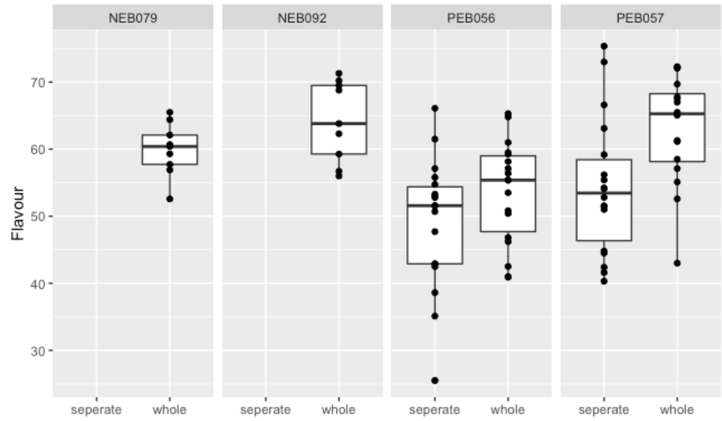


Figure 108. Comparison of consumer flavour ratings for brisket muscles cooked as entire cut or as individual muscles.

The beef rib TBQ results demonstrated a similar pattern to the brisket analysis. The ribs were cooked as whole bone in cuts then separated into component muscle portions, including dividing the covering *M. serratus ventralis* muscle into chuck (CHK178) and rib (RIB178) portions for sensory evaluation. Muscle effects were again evident as shown in Table 49 with the intercostals performing worst and an appreciable difference also noted between the chuck and rib portions of the *M. serratus ventralis*.

Table 49. Sensory trait scores for TBQ cooked beef rib muscles

Least squares means for muscle

CUT	Tenderness	Juiciness	Flavor Liking	Overall Liking	MQ4	Satisfaction
CHK178	56.1^{b}	48.9^{b}	53.5^{b}	53.0^{b}	53.7^{b}	3.00^{b}
INT137	55.2^{b}	46.6^{b}	45.8^{c}	45.9^{c}	48.8^{c}	2.81^{c}
RIB178	72.2^{a}	66.3^{a}	60.9^{a}	63.8^{a}	65.6^{a}	3.41^{a}
SEM (largest)	2.5	1.9	1.6	1.7	1.7	0.05
P-value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

^{ab} Within a column, means sharing a common superscript, do not differ ($P < 0.01$).

4.3.8. Freeze thaw ageing evaluation.

Logistical considerations within individual plants often impact decisions on whether selected cuts will be held chilled or frozen immediately after boning. In general bone in cuts and some of the larger secondary items including insides, outsides and chucks are often frozen 1 day post kill to enable high value items to be chilled and align production to optimise chiller and freezer capacity. With the expanding proportion of cuts marketed under MSA based brands this could result in reduced revenue due to MSA eligibility being restricted to a minimum of 5 days chilled ageing.

A project was initiated to generate MSA data on the potential for ageing after initial freezing, storage and thawing. Given suitable tracking and control systems, quantification of a post thaw ageing rate would provide a basis to pursue MSA approval of ageing after thawing, prospectively in a customer supply chain or distribution facility.

Paired cube rolls were collected from 18 grain fed Holstein steers. One from each body was frozen on plant in the plate freezer and the other prepared into 7 and 21 day aged MSA grill consumer samples at CSU. These control samples were frozen at 7 and 21 days and held frozen until 24 hours prior to sensory testing.

The final 17 paired frozen primals were divided into portions with a band saw 23 days prior to sensory testing, with the 21 days allocated piece thawed and the 7 day piece re vacuum packed until 9 days prior to sensory. After thawing the frozen samples were fabricated to MSA consumer grill samples and tested within the same consumer sessions as their pairs.

The adjusted consumer MQ4 means, and standard errors are displayed in Table 50.

Table 50. Adjusted Mean MQ4 after 7 and 21 days ageing for control (frozen after ageing) and freeze thaw (frozen 1 day post-mortem and aged after thawing).

Treatment	Days Aged	Mean MQ4	Std Error
Control	7	72.15	1.64
	21	71.32	1.6
Freeze & Thaw	7	72.78	1.6
	21	75.89	1.6

The consumer results are also displayed in Fig. 109 and illustrate the slight non-significant advantage to the frozen and thawed treatment. Given the low sample numbers and unusual lack of ageing between 7 and 21 days for the controls, the trend was considered unreliable but did indicate that post thaw ageing could be essentially equivalent to thawing prior to freezing.

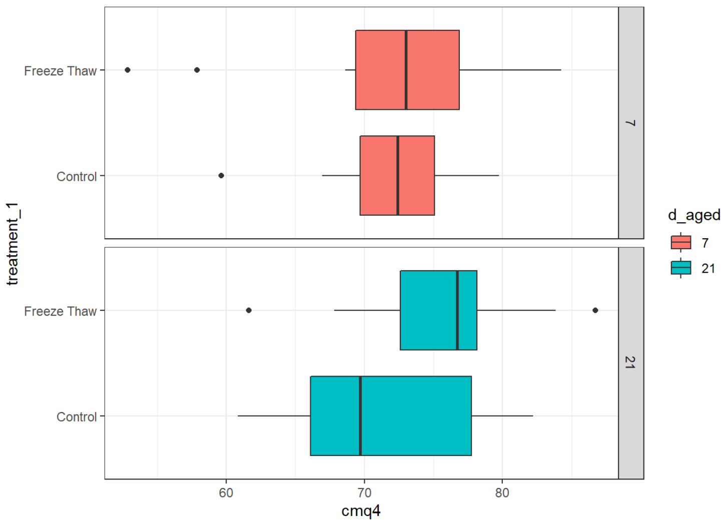


Figure 109. Control and freeze/thaw MQ4 at 7 and 21 days ageing

There are a number of caveats around that conclusion in addition to the low sample size including the possibility that freezing in full primal form may impact ageing relative to freezing after fabrication into consumer samples. The results were however encouraging and suggest that, subject to replication across further paired cuts, ageing after thawing could be included in MSA criteria.

4.3.9. pH relationship between muscles

The consistent interaction of pH in projects relating to value adding and packaging, including the serious consequences of an MSA ultimate pH reading above 5.7, generated a desire to better understand and ideally address the causes of non-compliance. A number of investigations were initiated related to pH declines and readings including comparisons across plants and between individual graders. A critical outcome was that there was a strong correlation between the recorded ultimate pH at grading and the time period between kill and grading, indicating that on occasions some carcasses had not reached true ultimate pH despite meeting AUS-MEAT and MSA assessment standards.

A recommendation was made that carcasses with pH marginally above 5.7 when graded after less than 36 hours from kill be identified and held back for a second assessment after a further period prior to final non-compliance action.

A further point of concern was the periodic very high pH non-compliance rates observed at the South Australian cattle in particular. It was doubted that the conventional explanations of stress during transport, insufficient feed or bad handling provided an adequate explanation. Some Victorian dairy work was investigated that had reported production issues with very high protein pasture intake, often associated with restricted intake typical of short high quality pasture during winter months. This work had indicated that when protein substantially exceeded minimal requirements in relation to metabolisable energy supplied, the excess protein was very inefficiently metabolised resulting in lower production than predicted from the actual energy intake. From models developed by the researcher a negative weight gain could result under these conditions as the available energy was utilised in protein conversion leaving insufficient for growth.

It was hypothesised that the same conditions, not dissimilar to the high protein pastures in south-east South Australia, could also be associated with the observed high pH problem. Discussions were held with the Victorian DPI and a tentative trial developed, but not proceeded due to the Department officer being recruited by private industry.

Routine careful recording of pasture type and quantity and further supply detail for all mobs with excessive pH non-compliance was recommended, ideally paired with data from other mobs in the same kill with excellent compliance to build a case control study base.

Given the very different pH relationships between three muscles in the similarly sourced meat colour and packaging trial the question was also raised as to the strength of pH relationship that might apply across carcase muscles; by inference, if the loin pH was 5.8 should the whole carcase be "ungraded" or were some other muscles likely to be within the range? If they were under pH 5.7 would they perform satisfactorily or were pH driven responses muscle specific?

The meat science literature was surprisingly thin on solid individual muscle pH relationships. To build a bank of knowledge arrangements were made to collect extensive pH data on up to 39 muscles from each of the bodies being yield tested in conjunction with the DEXA work. Where suitable labour was available this provided an ideal environment where cuts were being boned to strict cutting lines and identified reliably to body by being collected at a single position.

The results were informative and established considerable muscle differences as displayed in Fig. 110. These data raise important commercially relevant questions that deserve evaluation. It was very clearly established that individual muscle pH varied widely in this sample. Further data would be required to reliably confirm the degree of correlation between values.

This knowledge stimulates more fundamental questions as to how, or if, these values might interact with value adding, ageing and cooking treatments and the degree to which these could be modified by process interventions. It is believed highly likely that muscle pH significantly impacts cooked flavour development in addition to various literature that reports interaction with microbial development and subsequent spoilage in packaged meat.

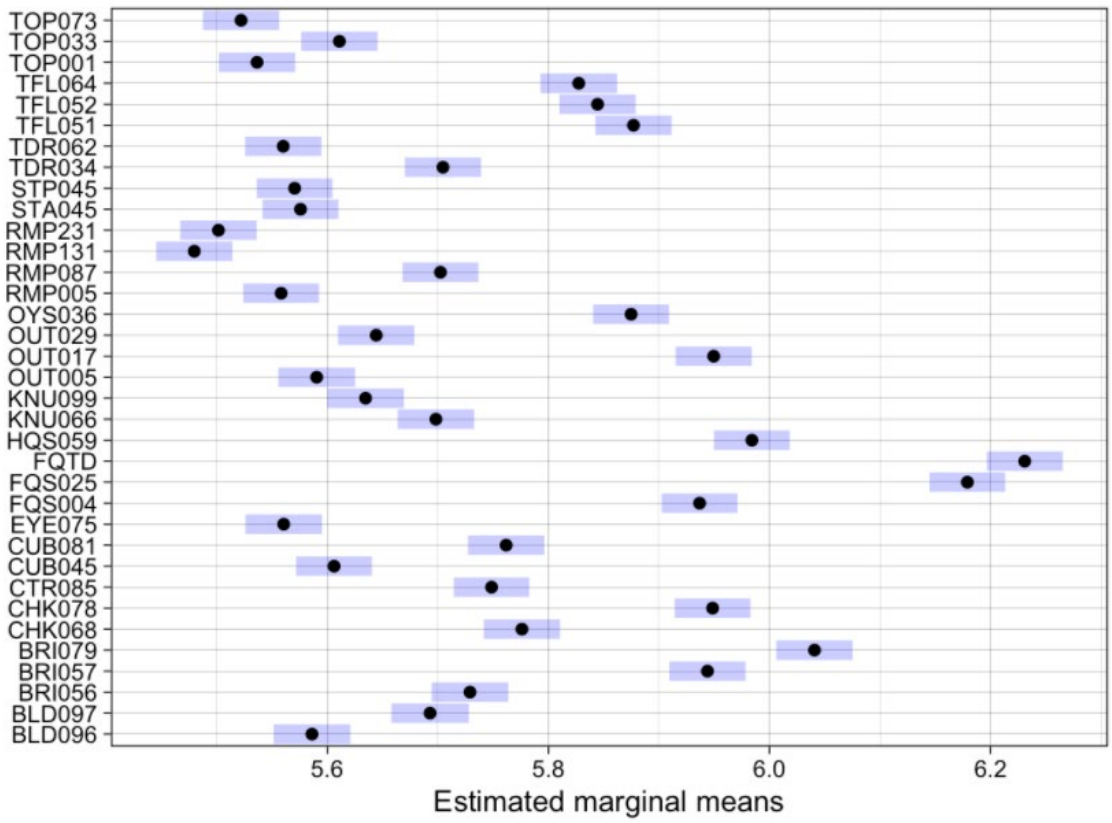


Figure 110. Individual muscle pH measurements from 95 similar sourced carcasses

4.3.10. Extended MSA eligible supply chains

The business, and the project, were also involved in MSA research designed to enlarge the eligible supply of MSA compliant cattle in conjunction with an MSA objective to be able to accurately assess all cattle types and production systems and complimentary interest in expanding beef supply.

4.3.10.1. Dairy beef

One significant possibility related to the use of dairy breed and cross cattle within eating quality based brands supported by MSA prediction. Traditionally dairy steers were viewed as manufacturing beef given typical presentation as 2 year or older large framed and very lean Holstein animals or as extremely light and unfinished Jersey types. When offered for sale the pricing offer had been typically based on cow beef pricing. Limited young dairy bull supply chains were also focussed on supply of lean product for manufacturing markets such as McDonalds supply and, in some cases, Halal markets specifying entire males.

This perception, and experience, was also reflected in dairy farmer attitudes and response, with the anticipated low return inhibiting retention and fattening. As a consequence large numbers of male calves were either euthanised at birth or sold as bobby veal. This reflected a huge loss of potential beef supply of increasing interest where kill volumes were low. Dairy Australia were extremely concerned with the reputational risk relating to poor animal welfare associated with euthanasia and transport of very young calves together with antibiotic residue issues.

Professional growing and fattening of dairy beef provided an opportunity to add a further 500,000 or so cattle to the quality beef supply chain while addressing the existing problems: potentially an industry win:win. Rod Polkinghorne had also reported on an intensive dairy based supply chain observed in Spain, England and Ireland created by Dr Octavio Catalan, a Spanish nutritionist who supplied specialised feed to finishers turning off over 1 million calves per year. Rod had spent a week viewing operations with Octavio in Spain and elsewhere in the UK and reported these cattle were hard to distinguish from purebred beef due to their accelerated growth and 280 to 300 kg carcase weight at 12 months of age. The specialised feeding appeared to modify the animals' maturity pattern toward a moderate maturity appearance. The presumption was, in common with other dairy beef consumer data from MSA protocol testing in Europe, that these cattle would have extremely high eating quality.

A major research project was initiated with as a partner, and including CSU and MLA funding, to evaluate production and eating quality relationships across a range of dairy types and possible production systems. The project utilised calves from Gippsland, the Victorian Western District and NSW Riverina and included Holstein, Jersey and Holstein x Jersey types plus some beef calves for comparison. Backgrounding at two target growth rates (0.8 and 1.2 kg/day) and finishing on grass or grain was included plus a trial of the "Spanish" ration. Cattle were to be harvested at veal and heavier (300 kg HSCW) points. A cohort of calves backgrounded on grass were evaluated as veal (<150kg HSCW) and a paired cohort finished in a Feedlot. These, and others from a second replicate, were processed with facility where collection of rumen samples from selected groups was conducted.

4.3.10.2. Long distance road and rail transport

The business was also heavily involved in substantial MSA research conducted to evaluate the carcase quality and consumer eating quality impact of extended transport including comparison of road and rail transport.

Large numbers of northern cattle remain ineligible for MSA grading due to the extended time from initial mustering to slaughter. The studies sought to evaluate both the direct effects of transport and the impact of alternative rest periods and feeding enroute or in lairage. A 13 and 35 day feedlot period was also included in one large study.

The business contributed heavily to these projects through cattle purchase, liaison with suppliers, organisation of rail transport, access for FLIR camera recording at the feedlot and abattoir and in facilitating extensive research activity including collection of samples.

It is anticipated that these, and a further planned replicate, will lead to new MSA Pathways that enable MSA eligibility and sound management advice as to optimum movement systems from station to slaughter.

5 Discussion

5.1. VBM

Development of a commercially viable value based marketing and cattle purchasing system was a core project goal requiring a detailed understanding of the relative contributions of lean meat yield and eating quality to ultimate value. While yield was of no consequence to the retail consumer it directly related to the actual weight of cuts sold within each of the brand based eating quality categories. Consumer value per kg was known to be directly related to the cooked meal experience with more accurate eating quality segregation achieved under an advanced branding strategy delivering increased value and supply chain revenue.

5.1.1. Yield measurement or estimation

The existing carcase measures of HSCW, sex, P8 fat and butt shape utilised in cattle purchasing grids provide poor yield estimates, a point worth remembering when evaluating alternative new technologies. Analysis of prior VIAScan data established that yield estimates could be improved by weighing a large carcase portion and or selected cuts in addition to the existing carcase measurements. This was evaluated for possible application using load cells on the side chain but discarded as impractical. A yield study of diverse muscle type cattle conducted by MSA to establish the MSA Index also established that muscle weights were well correlated indicating that accurate measurement of one or two with consistent cutting lines could provide a reasonable estimate of others. This agreed with earlier published work by Butterfield.

A detailed appraisal was conducted of EMA measurement to establish variation between graders and between carcase sides. This established moderate side differences (correlation of 0.7), likely to also apply to muscles in general introducing some error into any single side based evaluation or side to side comparison. While the formulae utilised are acknowledged as imperfect, they provided a consistent base for estimation and established a substantial economically important variation within and between plant cattle populations.

An important practical consideration was selection of the most appropriate yield measure to report and utilise in feedback or prospective payment systems. While saleable meat yield (SMY) appeared attractive as it represented actual meat sold, it was discarded as impractical due to the complications introduced by literally thousands of individual cut codes with over 100 for some individual cuts relating to cutting lines and trim. Use of actual SMY therefore would report widely different relationships from consignment to consignment or even within a single boning room run. Adjustment to a standard SMY specification would also produce artificial results.

To avoid these issues lean meat yield (LMY) was adopted as the most appropriate measure as it provided a constant base for comparison and evaluation unaffected by cutting lines and trimming. The consequence of this however was the need to have authoritative conversions from all actual cut specifications (cut code SMY) to LMY to facilitate pricing comparisons. At a carcase level new technologies were judged as likely to provide high accuracy estimates of body composition and consequently LMY. Less certainty was ascribed to potential live animal scanning systems although these were regarded as promising and potentially of significant value for live animal or hide-on carcase assessment.

5.1.2. Eating quality estimation

The MSA models predict individual muscle eating quality outcomes for a number of cooking methods, further adjusted for days ageing. This base provides a detailed ability to allocate cuts (from their component muscle or muscles) to prescribed eating quality categories. This provided the fundamental basis for developing the brand strategy which was focussed on delivering consistent cooked meal experiences at up to three alternative quality and value points.

Project work included individual muscle MQ4 (the MSA eating quality statistic, a score between 1 and 100) analysis on over 4 million cattle with up to 300 muscle by cooking method outcomes per body. These data were utilised to establish brand technical specifications subsequently applied to carcase sorting.

Under the existing side chain boning system however “perfect” sorting of cuts to defined quality bands is not possible as the “first cut to fail” from a side causes the side, and all other cuts, to be rejected and moved to a lower category. Individual muscle MQ4 is not well correlated due to many factors including breed type, HGP treatment, ossification, marbling and ageing impacting differently on each muscle. While cut-off scores for individual cuts within each brand based PBR were adjusted to minimise this fallout the reality was that payment on the basis of individual muscle MQ4 or MQ4 band would not relate directly to sales and create a pricing risk if adopted. This also applied to payment or categorisation using the MSA Index which assumed standard cooking methods, AT hang and 5 day ageing for all cuts where in practice the developed PBR settings utilised many alternative cooking and ageing criteria.

To provide transparency and a clear relationship between actual product sales, ultimately reflecting consumer value, and the purchased animal the PBR was adopted as the eating quality measure as it represented the actual allocation of carcase cuts and sales value.

Analysis on this basis over the project period resulted in commercial adoption of a 5 tier PBR structure that directly related to branding and provided effective carcase categorisation at all plants, with 3 of the 5 categories utilised at individual plants to suit their supply base. A significant eating quality range was found in all cuts leading to large value differences.

The existing cattle purchasing grid structure was extensively discussed with staff and non eating quality or yield factors identified. These related to market eligibility and brand provenance criteria including organic, EU, Free Range and Angus, in addition to some “off grid” transactions relating to volume, seasonal supply or other arrangements such as forward contracting. In the final VBM pricing evolution these factors were separated from the cattle purchase cost to ensure evaluation of yield x eating quality combinations were not distorted.

5.1.3. Analysis systems and supplier feedback

VBM analysis was progressively developed over several years to firstly develop a suitable technique, then develop an appreciation of the variation in value and contributing balance of eating quality and yield, and finally to relate this to transparent and actionable communication.

Prior to company adoption of a comprehensive eating quality based PBR structure conceptual Platinum, Gold and Silver (PGS) categories were developed and used to allocate carcasses to eating quality bands based on historic and current data. In these and later analyses data was evaluated in monthly increments for each plant and subdivided into grain and grassfed categories. In the most recent work further brand specific analysis were also included.

The PGS analysis was comprehensive and provided a solid understanding of the MQ4 variation within each cut and across cattle populations, seasons and plants. When combined with lean meat yield estimates highly significant individual animal differences were identified. These analyses provided background to the relative influence of yield and eating quality which was found to differ between plants and naturally within individual animals and consignments. The VBM basis was adopted as the most transparent and relevant to a potential commercial application. Extensive modelling was conducted to evaluate potential returns under different PGS pricing scenarios with either direct $/Kg assignment to individual cuts or % increments from an Ungraded or Silver base.

To provide a base for comparison between the actual payment system and a theoretical VBM basis it was elected to conduct analysis within a common $ pool being the actual total monthly livestock payments for each plant. This common pool was reallocated under the VBM scenarios and then the actual purchase cost and VBM allocation compared on a per head and $/Kg HSCW basis for each carcase. Five alternative analyses were tested being pure LM Kg, MSA Index (representing either only yield or only eating quality), a 50/50 allocation between the two, brand and a true VBM basis of LM Kg x PBR $/Kg LM. Results were summarised to display difference at minimum, 1%, 5%, 25%, 50% (mean), 75%, 95%, 99% quantile and maximum values.

As the plants transitioned to a more comprehensive EQ based segregation system actual plant PBR allocations were utilised in VBM evaluations, again for extended one and two year periods in monthly increments. These analyses produced evidence of similar value distribution to the earlier more theoretical base. From these results a conceptual pricing grid format was developed and extensively discussed with the grid aiming to clearly differentiate value components including non-yield and EQ factors including carcase weight, market eligibility and provenance. LMY% was added to producer feedback sheets together with a simplified graph that displayed MSA Index relative to yield categories. An R based Shiny App program was also developed and presented as a possible concept for feedback and analysis through an on-line portal. The Shiny App provided an ability to sort results on selected parameters including gross return, difference to the traditional grid and weight plus graphical representation of key traits, individual animals within a mob and relationship to other consignments.

In the most recent period, following introduction of the MSA V2.0 model and commercial introduction of more sophisticated brand related PBR, analyses progressed utilising enhanced Birkenwood software that enabled marketing and brand criteria to be included in selection and automated processing. In this iteration non yield and EQ pricing factors were separated and VBM values calculated on the remaining amount. As the actual plant PBR settings were those developed by Birkenwood the EQ price component of the VBM calculation was applied within PBR to more accurately allocate pricing.

Analysis was extended and automated to provide analysis on a consignment mob basis to enable comparison of total producer returns for a consignment in addition to individual animal differences between the current and VBM structures.

A new more sophisticated VBM analysis tool was developed within an R Shiny App framework to allow input of non-yield or EQ price factors using sliding scales and direct loading of files from the core Birkenwood system which provided extensive selection options related to plants, time periods, feed regimes, market access and branding criteria. The output was also extended to provide the summary VBM output utilised in the earlier iterations in addition to the summary feedback data and graphical presentations. The package is believed to provide a highly commercial analytical tool to evaluate true value in real time. It also provides a detailed base that could be readily adapted to daily commercial application.

The potential of a VBM structure was exhaustively evaluated and successfully developed in detail over the course of the project. Consistent significant differences in true animal value, of several hundred dollars per head, were identified providing evidence of the potential efficiency improvement that could flow if an introduced VBM system stimulated change in the cattle supplied. Given that the costs to breed, finish and process a low and high value animal are close to constant a transition to the mean cattle supply eliminating the lower percentiles of the current population and increasing those of higher value has huge industry and company significance, arguably being one of the largest potential drivers of profit or competitive advantage.

The project has quantified the value differences and developed commercially practical delivery systems. While more accurate yield measurements will become available the current formula remains significantly better than existing carcase inputs. The adopted PBR structure provides direct consumer related value points.

The main challenge to implementation is cultural, with extensive communication essential to building understanding and trust between cattle suppliers and the company. In a period of extreme short supply and record cattle pricing immediate introduction has been considered to pose too great a risk but the potential gains remain extraordinarily high and warrant continued engagement.

Pilot VBM and VBP programs with selected like-minded suppliers and tracking of company cattle was recommended together with adoption of superior yield systems as they become available.

5.2. Branding

Throughout the project period there was close and continual engagement with the marketing and sales teams. management placed a high priority on utilising base MSA capability, enhanced by Birkenwood analysis and software, to build brand alignment with consumer sensory experience. It was recognised that traditional branding approaches based on a breed, feed or marbling story often failed to deliver a repeatable eating experience and were also very similar to competitor offers. Segregation of cuts into brands traditionally related to dentition based cipher groupings of carcasses within MSA Boning Group ranges into boning runs within market eligibility. Carton labels carried basic MSA description and traditional AUS-MEAT carcase descriptions. Under the MSA boning group structure in effect this delivered a common 46 MQ4 point (3*) minimum for all but a few sweet cuts providing an MSA/not MSA division for the majority of the carcase with significant variation, potentially from 46 to 100 MQ4, within a common carton label.

The Birkenwood software enabled allocations to be made on any MQ4 score rather than only on 3* (46 MQ4), 4*(64 MQ4) or 5*(77 MQ4). This provided dramatically greater opportunity for segregation and the ability to elect cut-off scores that would allocate a desired proportion of product into brand based categories. This potential, and branding implications, was presented to the marketing team in conjunction with consideration of the branding strategy.

5.2.1. Baseline studies

Initial branding work was initiated with marketing workshops to gain an insight into the branding aspirations and primary market characteristics which might drive the number of product levels and relative proportion of product desired within each. Discussion indicated that uniformity of product experience was a key objective regarded as central to differentiation and pricing premiums over general MSA product labels. To achieve this it was agreed that up to three eating quality (EQ) tiers would be considered for each cut where there was a sufficient range of MQ4 eating quality scores. It was agreed that a general target of 25% premium, 50% mid-range and 25% entry level MSA quality was appropriate.

After a standard file structure was agreed with IT, data was downloaded to Birkenwood and processed in monthly files of grass and grain fed cattle for each plant. An initial 12 months data was utilised for analysis and expanded progressively. Production personnel were consulted to understand the existing systems for carcase allocation to boning and the use of Cut Families and Product Specification nomenclature. The downloaded files included kill floor and MSA grading input data which was initially analysed. It was noted that tropical breed content was most often noted as 110, causing the MSA predictions to be conservative and to assume an often higher than actual bos indicus content. Calculations were made to quantify this impact at various HSCW, and actual content points and workshops held with livestock personnel to recommend more accurate estimates where content was known. Adoption of this recommendation resulted in improved MSA grading outcomes across the northern plants.

Further analysis was conducted across MSA boning group and dentition groupings and the minimal relationship of dentition and EQ observed. Again, this was brought to management attention together with discussion of the potential to reduce dentition based carcase segregation given that MSA sorting was a final step with the additional sorts, a further complication. Replacement of dentition with EQ based sorting offered more effective EQ segregation within a common number of boning room changeovers.

These and other recommendations and contributing analysis were circulated in detailed written reports and summarised in PowerPoint presentations.

Each source file was then processed through Birkenwood software to calculate the MQ4 score for each of the 39 muscles or cuts in the MSA SP2009 model for each of the 800,000 or so MSA eligible carcasses that had been graded over 12 months. Within each file counts of cuts within MQ4 score were made to produce score distributions. This enabled calculation of the number and % of each cut that would have been collected within any MQ4 score range or above and below notional cut-offs. This extensive base was overlaid with adjustments for alternative cooking types and ageing related changes. A subset of files was also converted to tenderstretch hang and re-run to determine the potential impact of adopting the tenderstretch hanging method.

Marketing workshops were again held to discuss the options for cooking method and ageing settings and their relationship to cut-off scores, harvest numbers and consumer experience. Whereas the existing MSA carton labels carried multiple cooking options it was agreed that where feasible this should be reduced to a single recommended method. It was agreed that the label should be a recommendation for use and guarantee of performance. As in a car sale the sportscar and 4WD warranty related to different specific uses.

A further fundamental decision related to whether grade (PBR) cut-off scores should be common across cuts or specific to each cut. It was agreed that the settings should be cut specific but, where muscles were similar for a specified cooking method, the scores should be aligned to enable packing under common usage descriptions such as Premium stir-fry, for example, if desired.

5.2.2. Extension to MQ4 based PBR.

The initial analysis data was then utilised to develop prospective Platinum, Gold and Silver (PGS) brand categories with specific cooking methods assigned to each cut and ageing varied in relation to the degree of improvement. Cuts such as tenderloin that had very low ageing potential were set to 5 days whereas as others with high ageing potential were more commonly set at 28 or 35 days. Twenty-eight of the possible 39 MSA graded muscles were included in the PGS modelling to enable packing of a greatly expanded range under MSA licensed brands. This required extensive adjustment of relative cut-off scores to ensure that priority cuts were not downgraded due to a less valuable cut “failing first”.

Initial settings were run on diverse cattle populations based on plant, season, grass or grain fed and for categories such as HGP and HGPFRE or 0 and 100% TBC to gain a detailed understanding of the myriad interactions generating the harvested numbers. Once completed all monthly files were run and the data accumulated for presentation and discussion.

These results were then utilised to develop financial models built from a base of cut numbers and through yield % to kg of each cut within each of the PGS grades and ungraded category. These calculations were made for each of 12 months for grain and grassfed categories within each of the 5 plants. A pricing table was then overlaid with $/kg for each cut within each grade category for grass and grain fed. The returns were then calculated, and the model utilised to predict outcomes under alternative brand pricing structures.

The same model base was modified to accumulate cuts within MSA Boning group ranges as utilised in the business and the gross returns compared across multiple scenarios. The results indicated that substantially greater revenue could be obtained through implementation of the recommended brand settings which introduced differential branded pricing within tighter EQ bands and marketing of additional cuts under an MSA supported structure.

5.2.3. Refinement and commercial deployment

Introduction of a new expanded MSA V2.0 model required extensive re-evaluation of cattle populations and model characteristics as a prelude to reviewing brand settings. A further 18 months of data was assembled with monthly grain and grassfed populations for the 5 plants as done previously. The Birkenwood software was also extensively upgraded greatly reducing processing times and adding features that automated assembly of groups meeting noneating quality criteria in addition to adding the new model and the ability to contrast output. Extensive analysis was conducted comparing cattle populations across both models with identical settings, identifying the cause of differences and then in refining settings with the muscles graded extended to 43 with additional ageing possibilities and cooking methods.

Following this, detailed meetings were held with marketing and market analysts on a minimum weekly basis to further refine the brand strategy and related brand map provenance and eating quality matrix. A 5 tier PBR structure was developed and tested extensively across cattle categories, brand groupings and plants by month. Detailed comparisons of cut capture were produced for discussion and trade-offs between cut volume and premium settings analysed and debated. The final structure provided a useful branding basis across all plants with the upper 3 PBR mostly relevant to the southern plants and the lower 3 to the north. It was strongly recommended that an entry level brand tier be introduced to provide a price competitive offer and to act as a comparison point to leverage premiums for the upper level brands. The fifth PBR was also designed to provide a consistent raw material specification for application in meat products value adding operations.

The final settings provided improved brand volumes relative to those for the previous model while adding further cuts and clear differentiated consumer value choices.

To support sales and marketing staff a comprehensive cut marketing manual was produced that provided information on the basis for the new brands and underlying technology together with comparison to alternative international grading systems. Detailed individual cut discussion followed providing advice on each cut within grade categories including rankings under alternative cooking options, ageing potential and possible substitutes. This manual was adopted as a training resource and supported a strategy to move sales staff from a purely transactional role to becoming trusted advisors to the client base though their technical expertise.

The sales offer was to become “the carton lid” which provided a category or brand backed promise of consistent eating quality and related provenance. The business bore responsibility, and provided the expertise, to match this and the selection of cuts/muscles within the carton, to clear consumer outcomes. The customer was relieved of the responsibility of attempting to obtain an outcome by extensive specification of cut and cipher. This was designed to deliver a genuine “win-win” outcome where the customer required less specialised meat knowledge but received more consistent product outcomes, creating higher value and a commensurate revenue opportunity.

The new system was successfully introduced across all plants in September 2020, the culmination of several years of collaborative development involving strong collaboration between Birkenwood and production and marketing teams.

5.3 Value adding

The project developed substantial proof of concept for value adding via enhancement of lower quality cuts and Texas BBQ cooking of briskets and ribs. Substantive proof of the negative eating quality impact of some modified atmosphere packaging systems was also delivered and a long standing believe that meat colour and pH at the time of grading were valid indicators of appearance at retail and of consumer acceptance was debunked. Industry and company understanding of meat colour chemistry and the implications for colour optimisation through to retail display was materially expanded by the sponsored visit of Professor Melvin Hunt, a renowned world expert. Two major studies developed a robust consumer visual scoring system and examined visual and eating quality packaging effects over a 9 day display period. Further packaging work produced extended ageing curves for multiple cuts and a pilot study addressed the potential for ageing after freezing and thawing.

5.3.1. Enhancement studies

The three enhancement project studies all established highly significant eating quality improvement potential with commensurate consumer willingness to pay by both Australian and USA consumers.

Results from the Meat Products study demonstrated similar MQ4 improvement over untreated control product with traditional tripolyphosphate and novel kiwifruit and ficin alternatives, with no additional improvement from needle tenderising, but raised a warning that despite increased eating quality consumers did not fully embrace the improvement, requiring higher than normal fresh meat MQ4 values to assign a higher quality category. Analysis established higher MQ4 cut-off values for each grade category and a substantial increase in the flavour component of the MQ4 score. Allied flavour chemistry at AFBI indicated minor volatile (odour) molecule changes but substantial differences in sugars, including an additional sugar not found in beef muscle within the enhanced product. Anecdotally consumers also reported a salty taste associated with enhanced product. The enhancement benefit was found to be greatest at low raw material quality levels and to reduce as raw material quality increased, resulting in raw material differences being reflected at all levels, but less so at the high end. The variability in low end raw material was reduced by enhancement with the project providing guidance on raw material selection.

A following extensive study of grilled product, drawn from a diverse and structured range of carcase quality from USA and Australian sources, further examined enhancement options replacing the kiwifruit and ficin treatments with calcium carbonate (soda ash), calcium bicarbonate (bicarb), a modified potato starch and a commercial natural beef stock. The bicarb, potato and natural stock provided potential “clean” label alternatives while the sodium carbonate and phosphate were commonly used in the USA industry. The previous finding that the enhancement effect was greatest on lower quality raw material and decreased as raw material quality improved was substantiated.

All options outperformed the control with the beef stock unexpectedly effective for tenderness in addition to the hoped-for flavour improvement. The potato starch product proved very difficult to physically manage with the beef stock and bicarb alternatives consequently favoured for additional development. A smaller study on fajita meat evaluated bicarb against phosphate and untreated controls, again with both treatments substantially above the control product.

From the combined project outcomes and insights a prospective new production approach was developed for discussion with a schematic representation shown in Fig. 111.

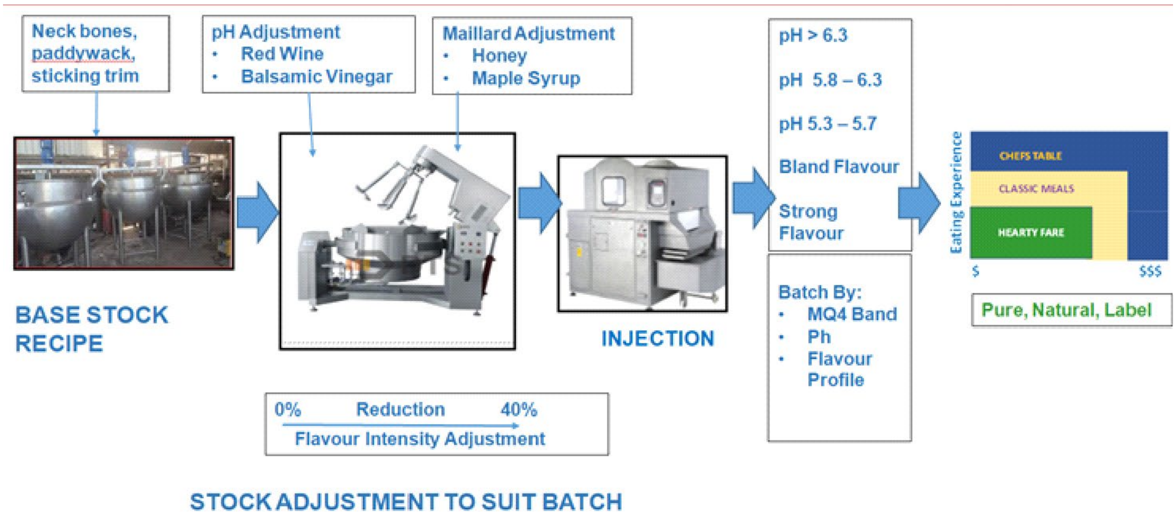


Figure 111. Conceptual enhancement process to develop consistent quality "clean" label products

As visualised a base beef stock would be produced at selected primary processing sites utilising neck bones and paddywack collected on the kill floor together with Halal stick and other lower grade or microbially sensitive trim plus selected bone belt material. This base stock would then be adjusted to suit specific process batch criteria. The traditional chef technique of reducing stock to increase flavour provided a potential mechanism to adjust final product flavour intensity, with the degree of reduction related to the raw material and desired final product characteristics.

The adjusted stock batch would then be amended as necessary to standardise pH, conceptually by adding natural ingredients such as balsamic vinegar or red wine that would be attractive on a retail label, and further adjusted to stimulate or modify the cooked Maillard effect by adding natural sugars such as maple syrup or honey. The bicarb results also indicated that strategic addition in the stock might provide additional tenderness modification with the final label being natural beef stock (beef, vegetables, maple syrup etc).

The proposed process aimed to influence the cooked beef flavour by modifying the precursors rather than the traditional approach of masking bland or unusual flavour by adding a sauce post cooking.

This concept provided a further means to utilise diverse raw material with batches specified by initial MQ4 and muscle type (collagen, fibre type, flavour profile, pH) to produce tightly specified MQ4 outcomes in conjunction with industrial cooking processes. An initial target was seen as utilisation of carcase meat failing on pH, with potential categorisation into pH bands from 5.71 to 5.9, 5.91 to 6.1 and >6.1 or similar to reduce losses incurred in downgrading. By developing tightly controlled evidence backed processes potential existed to develop distinct and consistent RTH or RTE branded cooked product lines.

More detailed value adding development work to define operational procedures and examine the impact of differing reductions and pump rates, etc, was recommended and could be confidently progressed from the initial proof of concept.

5.3.2. Packaging and ageing studies

The three packaging studies and incorporated ageing comparisons have already heavily influenced industry and retail practice, not always with enthusiastic engagement. The initial study was designed around a primary objective of evaluating meat colour with particular reference to MSA criteria that rejected any carcase with greater than an AUS-MEAT meat colour 3 score at the loin grading site. The findings were confronting, indicating that colour at grading had a very poor relationship to final retail colour and consumer preference. The relationship was essentially non-existent for non-loin cuts.

It had been noted in observational work prior to the main study that some grassfed bullocks had an atypical pH to meat colour relationship at grading causing an MSA meat colour rejection while being compliant for pH. The study evaluated pH and meat colour on tenderloin, cube roll and rump muscles at grading (loin only), boning, after 5, 12 and 40 days ageing and after up to 9 days display in a retail cabinet. The results established that initial pH at grading provided a superior relationship to consumer meat colour score relative to actual meat colour at grading. This directly resulted in industry agreement to remove meat colour as an MSA requirement while retaining pH, a result that improved MSA compliance without compromising the consumer experience. It was also noted that dentition did not impact meat colour at any time point, providing further evidence that it should not be considered as an eating quality or visual indicator.

A further outcome of the project was the development and practical evaluation of a consumer meat colour scoring (CMC) system that related 100 mm line scale ratings of colour relative to choices, on the basis of appearance, of “definitely would buy”, “definitely would buy if discounted” or “definitely would not buy”. The ratings and CMC proved very effective with strong correlation between consumers in this and a subsequent study.

The retail viewing and subsequent consumer sensory appraisal also incorporated alternative overwrap (OWP), high oxygen modified atmosphere (MAP) and vacuum skin packaging (VSP) comparisons which again had considerable industry repercussions. The MAP packaging was found to significantly reduce consumer scores regardless of the cut or prior vacuum packed ageing period. Given the widespread retail utilisation of MAP in conjunction with central packaging arrangements these results raised concern and further questions as to whether the impact might be similar with cuts from southern, younger or grainfed cattle and whether the strong 12 MQ4 point decrease might reflect testing at use-by date and be substantially less at earlier retail display days.

The second study addressed these concerns by only utilising southern MSA eligible grass and grainfed product balanced across three PBR levels from base to high end MSA. Only striploin and cube roll samples were tested with an initial vacuum packed 16 day primal ageing period. The original MAP and VSP packaging methods were retained and two MAP variants, a tri gas mix with reduced oxygen level in conjunction with carbon dioxide and nitrogen (TRI) and a high nitrogen mix with no oxygen (NIT) also evaluated. Product was viewed at 1, 3, 5, 7 and 9 days and also consumer tested at each period.

Again, the CMC scores were consistent, in both cases favouring MAP as being slightly more preferred to VSP, but to a less significant extent than expected. The TRI was also viewed favourably whereas the NIT product was universally rejected from days 1 to day 9. The MAP and TRI CMC scores declined somewhat over the display period but remained above those for VSP and NIT which remained more stable. Results on mince packs were similar. In contrast the consumer sensory evaluation rated VSP and NIT highly and discounted both MAP and TRI considerably. This effect, attributed to oxygen levels, was evident from the day 1 samples and throughout the display period. The study confirmed the MAP MQ4 deterioration and resulted in an MSA 8 point deduction for high oxygen MAP.

The Thermoform study primarily aimed to evaluate ageing periods beyond the 50 day maximum contained in the MSA V2.0 model made relevant by extended delivery times into the China market in particular and in recognition of 120 day use by advice provided by the company. Thermoform was regarded as conservatively similar, and perhaps slightly more liable to deterioration than conventional shrink bag vacuum packaging. The study consequently had no packaging comparison but generated data in 7 day increments from 21 to 140 days of ageing for a number of cuts commonly supplied to the Chinese market including shin and heel muscles and intercostals together with brisket, chuck, cube roll and striploin.

Other than leakers the majority of product remained acceptable to the 140 day limit but typically declined somewhat from around 70 days as a result of flavour deterioration. As flavour was also directly related to MQ4 reduction in the packaging studies and implicated in the value adding work ***it was strongly recommended that more fundamental and extensive work be conducted on flavour mechanisms*** with a view to both developing practices that reduced the deterioration or alternatively modified flavour precursors to positively adjust flavour outcomes when product was cooked. It was also acknowledged that microbiological mechanisms were likely to contribute, with flavour likely to be interrelated with muscle type, pH, initial micro loading including species, packaging materials and internal atmospheres, ageing temperature and time and the final cooking process.

Given current attention to environmental outcomes and concern over plastic packaging it was considered likely that alternative packaging forms would evolve in the near term, with consideration likely to focus on the environmental and contamination aspects. ***The need to include comprehensive consumer sensory assessment within packaging studies was emphasised in light of the previous study results.***

The opportunity to expand MSA product lines through ageing product after freezing, shipment and thawing was also explored by a small initial project that directly compared paired cube rolls either aged pre or post freezing to 7 and 21 days. The results indicated that both treatments generated similar consumer outcomes. ***It was recommended that a more comprehensive study be conducted including several cuts with different muscle characteristics*** as a successful outcome could enable MSA accreditation to be maintained where eligible cuts were frozen due to restrictions on chill tunnel capacity or storage.

5.3.3. Brisket as a premium product

The project work relating to TBQ cooking of briskets and ribs established that a very high quality consumer experience could be achieved with commensurate opportunity for marketing under premium branding and pricing.

The studies also quantified differences in individual brisket muscle outcomes relating to raw material potential, between serving styles and between restaurant style serving after cooking relative to reheating after a chilled retail display period. Each of these findings could be applied commercially to segregate product and achieve more consistent consumer value alternatives allied with pricing.

A recurring issue relating to unpredictable and erratic cooking times was not resolved by cooking individual brisket muscles rather than as a whole primal and remains a production challenge for batch cooking in automated ovens. An opportunity was foreseen in providing individual graded brisket or rib portions to restaurants in a smoked, partially cooked state where they could be individually monitored in the final cooking stage to deliver a guaranteed premium consumer experience.

It was recommended that further development work be conducted regarding controlled cooking processes including evaluation of "liquid smoke" which could provide more consistent smoke addition in conjunction with reduced potential carcinogen risk.

5.3.4 Expanded MSA supply eligibility.

The dairy cattle supply studies provided proof that dairy cattle could be successfully utilised in quality oriented programs. While the Jersey breed was found to be largely unsuitable due to slower growth and less efficient low carcase weights the Holstein cattle had highly acceptable growth and carcase performance when fed to achieve a high lifetime growth rate. It is expected that more intensive feeding aimed at a 12 months of age 300 to 350 Kg HSCW would produce a premium quality article by modifying their maturity pattern and carcase characteristics. This is yet to be confirmed from a current group of trial cattle but being observed from commercial groups currently on feed at the Jindalee feedlot and testing of equivalent cattle in Wales by Birkenwood.

6 Conclusions/Recommendations

The project successfully examined and developed an effective consumer focussed VBM and VBP structure across the business which encompassed a considerable range of climatic and associated cattle variation. This required development of key principles that could be differentially applied and adapted to suit different locations, populations and market conditions.

A fully consumer focussed marketing structure was implemented to support strong brands with both eating quality and provenance criteria and has produced enhanced returns for the company, customers and suppliers, a genuine win:win model that can be expanded further through implementation of a more precise VBP livestock model that would be expected to generate improved cattle supply with associated efficiencies and profit generation across the value chain.

Currently available yield prediction systems are less than perfect but at this point substantially better than traditional carcase grid specifications. It is anticipated that new technologies now being trialled commercially will deliver improved accuracy and encourage VBM uptake. Current extreme cattle market conditions have also demanded that any fundamental change to trading systems be hastened slowly to avoid risk from either poor acceptance and related supply contraction or through unforeseen financial interaction under a new structure.

The substantial variation in livestock value evident from extensive analysis however strongly supports continued development with the physical, communication and cultural challenges more than offset by fundamental industry-wide long term change; in truth to a new paradigm of collaboration across sectors for mutual benefit. The key to this outcome is a continued very tight consumer focus with revenue and payments at all points directly related to consumer value delivered relative to competitors and competitor products.

The project work has also generated further knowledge and support for value generation through increasing the consumer value of initially low quality raw material to highly acceptable levels through multiple value adding processes. Processes relating to enhancement, packaging and new cooking methods have each demonstrated significant eating quality gains and the potential to provide “clean” label higher value retail and food service offers. Further development work on processes and in particular on better understanding flavour mechanisms can add additional value.

6.1. Recommendations

Core recommendations arising from the project include:

1. Development of a transparent value based pricing and marketing structure be continued due to the substantial potential economic benefits that accrue. It is predicted that effective implementation will be a catalyst for long term industry prosperity through increased consumer relevance and delivered value relative to competitors.

2. That pilot programs with like-minded core partners and company owned cattle be progressed to develop practical experience within a VBM/VBP structure to enable refinement and gain confidence prior to wider introduction.

3. For consistent communication it is recommended that pricing and communication be based on lean meat kg. This will require company yield equations to accurately relate to the myriad individual cut specifications.

4. That consumer value, including additional product volume through enhanced yield in addition to eating quality differentiation, be the fundamental driver of marketing, branding, production and livestock purchasing systems.

5. That development of collaborative systems be backed by commensurate training of marketing, sale and livestock purchasing staff to transition them from a purely transactional role to being valued by customers and suppliers for their knowledge and ability to provide reliable advice and practical assistance.

6. That value adding research and commercial development activity be expanded with a view to revenue generation from traditional secondary cuts and prime cuts from secondary quality carcasses.

7. That value adding practices include, and potentially prioritise, higher quality and value products in addition to price based commodity offers. Components of this approach should include a commitment to “natural and clean” ingredient labelling and healthy nutritional balance, a natural benefit of beef based product relative to ultra processed competitor offers.

8. That the company directly, or though industry linkages, support further research into flavour mechanisms and the potential to commercially apply the outcomes to improve product value through pre-cooking intervention.

9. That available technologies to retain individual cut ID and enable cut specific segregation be continually monitored and, when judged economic, adopted to increase the efficient capture and segregation of cuts within eating quality categories. Under current side chain based systems a substantial proportion are in effect downgraded due to the “first cut to fail” causing the entire carcase to fall to a lower PBR.

10. That further product development effort be directed to utilisation of currently undervalued non loin cuts including separation of individual muscles and grouping of like eating quality or value adding raw material specification under usage rather than cut name criteria.

11. That formal MSA or equivalent consumer sensory protocols be utilised to evaluate and benchmark production, packaging, value adding and branding interventions.

7 Key Messages

Key messages arising from the project are:

1. Industry adoption of transparent Value based Marketing (VBM) and value based livestock pricing (VBP) systems could drive significant industry change and underpin future viability.

2. There is a huge range of value within cattle groups (several hundred $/head) that are visually similar and currently paid on common “average values”.

3. These differences reflect both lean meat yield and eating quality variances that relate to product weight sold and consumer value.

4. Lean meat kg should be the preferred unit of payment weight and reporting as it provides a consistent result across multiple product specifications.

5. Processor plant boning run or brand category is a preferred pricing mechanism as it directly relates to the value achieved for product sold.

6. The value differences tend to be more weighted to yield variation at lower eating quality levels and to eating quality performance at higher levels but both aspects remain critically important.

7. Well-developed consumer or customer focussed brands utilising an eating quality base in addition to provenance criteria should provide a clear description of consumer value and eating experience.

8. The matching of eating quality brands to an eating quality experience or meal occasion can supplant cut description reducing complexity and simplifying purchase specification.

9. Adoption of a usage terminology can increase flexibility within the plant through flexible cut allocation and represents a change from the customer requiring expert technical product knowledge to the company becoming the expert knowledge source able to precisely meet a customer requirement.

10. Additional revenue can be achieved from separating muscles of differing eating quality within traditional multi-muscle primal cuts.

11. There is outstanding opportunity to increase carcase value through further value adding processes that raise eating quality through enhancement, packaging or cooking procedures.

12. Further detailed flavour research is required to better understand and commercially apply the knowledge to improve consumer value. This is particularly relevant to value adding, long term ageing and packaging interventions, all of which interact with flavour development.

12. It is critical that formal MSA or equivalent consumer sensory protocols be utilised to evaluate and benchmark production, packaging, value adding and branding interventions to ensure that consumer value is not inadvertently reduced.

8 Bibliography

- P.PIP.0503 Investigation of the interaction of selected value added processes on selected cuts of varied quality.
- P.PIP.0488 Impacts on consumer acceptance of beef from interactions between pH, meat colour and packaging.
- P.PIP.0550 Developing capability for external strategic partnerships with experts from Texas Tech University (TTU) Meat Sciences and Muscle Biology Program.
- L.EQT.1813 Quantifying the impact of Modified Atmosphere Packaging (MAP) and alternative packaging solutions on eating quality.
- L.EQT.1814 Sensory evaluation of Australian and American briskets, striploins and ribs by Australian and American consumers utilising genomic tested cattle.
- P.PSH.1023 Creating a dairy beef supply chain to increase the value and volume of beef and veal products.
- AFBI Report. Effect of muscle, cooking, ageing and packaging on beef flavour volatiles. February 2017
- AFBI report. Update on analyses of enhanced beef samples 25th March 2018
- Garmyn, AJ, Garcia, LG, Spivey, KS, Polkinghorne, RJ and Miller, MF. (2020). Consumer palatability of beef muscles from Australian and US production systems with or without enhancement. Meat and Muscle Biology 4(1):1-12(2020)
- Garmyn, A., Hardcastle, N., Bendale, C., Polkinghorne, R. And Miller, M. (2020) Exploring consumer palatability of Australian fajita meat enhanced with phosphate or sodium bicarbonate. Foods.