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The science of red meat and its importance to New South Wales: A case study

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Abstract

Meat scientists are tasked to advance the red meat industry in New South Wales. This research has already provided valuable insights and measurable opportunities. Examples include investigations into Spirulina supplementation effects on lamb productivity and meat quality; optimisations to the precision and accuracy of laboratory-based meat science tools that reflect consumer experience; innovations in meat packaging technology; recommendations for long-term storage thresholds for frozen and chilled red meat; analyses of dark cutting and beef colour evaluations to predict carcass value; assessing the usefulness of novel colorimeters for meat colour appraisals; suggestions of novel forage-types that enhance red meat healthiness; and exploration of the means to accelerate the ageing process for beef. Each of these provides strong scientific foundations on which the New South Wales red meat sector can build to ensure meat quality and safety. This assurance is imperative to affirm market access, confidence and position; optimising production and processing efficiencies that mitigate economic and environmental cost; and boost the sector's social licence and broader recognition as a comparatively clean and green industry. Meat research must be dynamic so that New South Wales can benefit from its unique capability to deliver meat to match market specifications.

Keywords: Red Meat; Meat Quality; Smart Packaging; Preservation; Technique Optimisation; Consumer Appeal.

Introduction

Advancement of the red meat industry in New South Wales towards a secure and sustainable future deserves merit. In 2017, for example, this sector contributed approximately $17.2 billion to the State's annual turnover and provided a livelihood for more than 50,000 workers, many of whom live in rural communities (MLA, 2017). But beyond economic and employment value, advancement in the red meat industry is potentially more significant because it is engrained into our national identity. Australians are proud of our international reputation for clean, green and safe produce; we are active contributors to shaping the future of the red meat sector, and often claim patronage of its accomplishments (Coleman, 2018, Lockie, 2015). These historic links should not be taken for granted.

Meat scientists strive to improve and grow the red meat sector and doing so, remain committed to optimising both the consumer's experience and industry efficiencies. This includes research that identifies production system effects on red meat so as to: enhance its nutritional value (healthiness) and eating qualities; optimise meat storage practices to deliver superior preservation, reduce waste and permit greater market access and growth; find packaging technologies that boost retail-potential and intelligently inform prospective customers; and equip processors with methods to better achieve market specifications (both domestic and abroad). Holistic and practical innovation within these themes is vital and will deliver economic and societal benefits through a greater understanding of *science-in-agriculture*.

This paper aims to highlight some such recent achievements and share what has been their tangible benefit to the New South Wales red meat sector. Consequently, it should be recognised that this paper is a case study and does not aim to provide a definitive overview of all meat research presently undertaken in New South Wales. It should also be noted that in this paper, red meat is used to only refer to *bovine* and *ovine* meats (beef and lamb); other publications may use broader definitions.

Spirulina supplementation effects on lamb productivity and meat quality

Sheep raised for meat production can be categorised by their feeding systems, *viz.* extensive grazing systems that use traditional pasture mixes or intensive supplement-driven systems that use concentrate- or grain-based diets (Ponnampalam et al., 2016b). Whether a system is appropriate depends on animal genetics, feed resource availability, and market specifications. The implications from feeding system selection on muscle composition and meat quality traits are significant (Malau-Aduli and Holman, 2015b, Malau-Aduli et al., 2016). It is therefore important to validate the impacts of *novel* feed-types and supplements prior to their adoption. The edible cyanobacterium Spirulina (*Arthrospira platensis*) is one such novel feed-type — primarily due to its protein-rich content that includes many essential amino acids, vitamins, minerals, and fats (Holman and Malau-Aduli, 2013). This application as a livestock feed is further enhanced by Spirulina having better land- and nutrient-use efficiencies when compared to conventional feed-types (e.g. maize, wheat, barley, etc.) (Smetana et al., 2017). Furthermore, Spirulina is produced within nutrient-rich, liquid mediums and this has prompted its use to recapture nutrients otherwise lost to current waste streams (Dismukes et al., 2008). It is therefore unsurprising that Spirulina has been the focus of recent investigation.

Past research has reported several important observations when crossbred Merino lambs held under drought or non-drought conditions, were supplemented daily with one of three different Spirulina levels (Holman et al., 2014d, Holman and Malau-Aduli, 2014a). Lamb haematological metabolite profiles demonstrated that Spirulina supplementation had no detrimental impact on animal health and welfare traits (Malau-Aduli and Holman, 2015a). Indeed, the muscularity and growth-linked metabolites, creatinine and Υ-glutamyl transferase, were observed to *increase* with Spirulina supplementation (Malau-Aduli and Holman, 2015a). This was supported when lambs fed 100 g of Spirulina per day were observed to have superior growth rates and body condition scores to the control lambs (Holman et al., 2012, Holman et al., 2014c). It should be noted that this outcome was found in spite of Spirulina having no observable effect on lamb feed intake – that is, its supplementation was not causing animals to consume additional basal feed resources (Holman and Malau-Aduli, 2014b). Genetic-nutrition interactions were apparent as SNP frequencies within the *ovine* ADRB3 and other genes indicative of lean carcass composition found to vary with Spirulina supplementation, and then more so when lambs were held under drought conditions (Kashani et al., 2015a, Kashani et al., 2017). These observations were confirmed through examinations of *M. longissimus lumborum* intramuscular fat content wherein levels declined with Spirulina supplementation (Holman et al., 2014b). That said, the polyunsaturated fatty acid content of the remaining fat content did *increase* to support the conclusion of Spirulina's benefit to improving the nutritional value of lamb (Kashani et al., 2015b).

Together, these outcomes suggest that Spirulina can be adopted into existing feeding systems to improve lamb productivity and the achievement of meat quality objectives. Furthermore, the prevailing dry conditions and inconsistent feed availability experienced by many New South Wales lamb producers in recent times, emphasise the need for practical alternative and novel feed-types, such as Spirulina, to ensure economic and community persistence.

Validation of red meat eating-quality measurements

The quality of red meat is fundamentally determined by its appeal to consumers and their *subjective* eating experiences. To better understand the appeal of red meat, consumer responses are often defined as *major sensory characteristics*, being: 1) tenderness, which is the mouthfeel or texture of the cooked meat; 2) flavour, the combined perception conveyed by the senses of smell and taste; 3) appearance or colour when the red meat is retailed or displayed; and 4) juiciness or the moistness experienced/induced upon mastication (Ponnampalam et al., 2016b). A consumer sensory panel (trained or untrained) can be used to measure these traits. However, to capture reliable and robust data, such panels can be relatively time-consuming and expensive. As a result, meat scientists often use laboratory-based proxy measures to quantify these traits. But, as true for all instrumental measures, their usefulness ultimately depends on understanding their reproducibility and representativeness — alternatively, their accuracy and precision.

Shear force (SF) is a measure of the effort necessary to sever muscle fibres and is a routine instrument-based measure used as a proxy for the sensory testing of tenderness. Its association to meat myofibril structure and fat content has been confirmed using small angle X-ray scattering synchrotron technology (Hoban et al., 2016) and laser diffraction particle size analyses (Silva et al., 2018b). In addition, abattoir effects on carcass pH and temperature declines have been shown to be important factors that influence SF values and therefore perceptions of meat tenderness (Hopkins et al., 2015b). However, a survey of the SF methodology in articles published in peer-reviewed animal and food science journals found these were, in general, not comprehensive enough to permit correct result interpretation nor research repeatability (Holman et al., 2016a). It is likely that this failure could stem from an acknowledged non-standardised approach to SF determination *viz.* differences between method endpoint temperatures and cook method, tenderometers, blade type and crosshead speed selection, reported resistance and unit, fibre orientation, etc. (Holman et al., 2016a). Our research efforts to identify sources of variation in SF measures have prompted the identification of six technical replicates as the lower limit for satisfactory result precision (Holman et al., 2015a). Sample block status (frozen or thawed) and weight prior to preparation were found to be important sources of variation that should be included when reporting SF results (Holman et al., 2017d). Furthermore, meat sample preparation method (e.g. grill, microwave, *sous vide*, etc.) will influence SF values and also the degree to which these results reflect consumer panel opinion (Silva et al., 2018a). The adoption of these findings could provide meat researchers the tools to achieve a greater understanding of consumer preference.

Likewise, the methods for instrumental measurement of meat colour are not standard, most likely because of the variety of technologies applied to this task (Tapp et al., 2011). This should be considered when comparing research findings as even instrument aperture size, Illuminant and standard observer settings, and the muscle fibre orientation on the measured surface have each been shown to impact on colorimetric variability. Larger aperture sizes, Illuminant A and 10° observer settings, and myofibrils orientated perpendicular to the measured surface are found to best *capture* red meat colour (Holman et al., 2015b, Holman and Hopkins, 2015, Holman et al., 2014a). The value of optimising colour measurement precision is based on the common knowledge that consumers prefer red meat with a bright red colour and the need for an instrument-based, objective definition for this trait. To fulfil this requirement a web-based survey was designed to distribute standardised photographs of beef with known colorimetrics. (Holman et al., 2016c). More than 2500 respondents from around the globe then ranked these images and provided the data necessary to establish that when a^* values (being a measure of relative redness) were equal to or above 14.5, beef colour may be considered as acceptable (Holman et al., 2017c). Furthermore, demographic effects on this threshold proved negligible, although respondent nationality and gender did contribute to variation in the relative importance of colour to beef value. These results are valuable to assist in the correct interpretation of instrumental colour measures in terms of consumer colour appeal.

The *drip loss* of beef has been used to understand the juiciness trait of meat, more recently determined using the EZ-Drip Loss method (Christensen, 2003). This method was designed for use with pork, so it was necessary to confirm its suitability for beef. As such, we found an additional 48 hours of incubation was necessary to differentiate between beef ageing groups (72 hours in total) (Kilgannon et al., 2018). As a result, New South Wales beef processors are now better informed when using this tool to estimate consumer perception. In addition, lipid oxidation in red meat is often quantified using a thiobarbituric acid reactive substance (TBARS) assay, a process ostensibly providing insight into flavour and other organoleptic quality traits. In practice, this has resulted in several TBARS thresholds that supposedly prescribe consumer opinion of overall liking of a red meat product (Campo et al., 2006). But research has shown that when two different methods of TBARS quantification were compared, no relationship between the results of these methods was observed (Zhang et al., 2019). Furthermore, neither of the results of the aforesaid two TBARS methods had a significant association to beef sample flavour liking and intensity, nor overall liking when evaluated using an untrained consumer panel (Zhang et al., 2019). This suggests that untrained consumers cannot detect abnormal flavour development due to high levels of TBARS, an outcome potentially resultant from the *halo effect* — being the misevaluation of an organoleptic trait as a result of the bias or influence of another (Larmond, 1977) — which is common to untrained sensory panels. Consequently, the New South Wales red meat industry should use caution if adopting a TBARS limit to describe beef shelf-life and retail potential.

Nutritive value and eating quality of Australian lamb cuts

The prevalence of *heavy* lambs (> 25 kg) in the New South Wales flock has increased because of advances in animal genetics and production efficiencies. While this outcome may have resulted from carcass weight being used to calculate carcass value and thus financial returns to the producer, heavier carcasses are often discriminated against because of their relative fatness and concerns regarding cut fabrication (Hopkins et al., 1995). Specifically, when boned out, a heavier carcass will produce portions of excessive size and of a retail cost that is unsuitable for modern households and unacceptable to the customer (Fowler et al., 2018). To overcome this challenge, it seemed productive to obtain a wider understanding of fabrication techniques in lamb and other livestock species, and use these insights to improve the retail potential of larger lamb carcasses. The publication of an "Information Matrix for Cuts-Based Grading" (Hopkins et al., 2015a) provides this information; summarising lamb-cut eating quality traits, nutritional value, recommended cooking method and portion, and unique fabrication opportunities that merit commercial attention. It was apparent, however, that our understanding of these characteristics was not comprehensive, with paucities evident for many common lamb cuts (Hopkins et al., 2015a). These omissions could have implications on the access of New South Wales lamb to international markets (e.g. European Union, South Korea, Japan, etc.) where consumers use nutritional, culinary and animal background information to evaluate the worth of lamb (Fowler et al., 2018, Holman et al., 2016b). Hence, more research is required.

Innovations in meat packaging technology

Red meat packaging has evolved from its traditional role as an inert barrier that protects its contents from contamination and spoilage (Holman et al., 2018d). Recent innovation has now designed complementary functions that enhance packaged meat quality, longevity and/or retail-potential. These can be defined using the term *smart packaging* (Kerry et al., 2006). In practice, smart packaging includes antimicrobial and antioxidant coatings and inserts; sensors that communicate the degree of freshness or spoilage of the packaged meat; engineering customisations that advance consumer-ease, packaging integrity and durability; leak and tamper-proofing technologies; and more sustainable material options to mitigate environmental impacts (Holman et al., 2018e, McMillin, 2017). The adoption of these emerging packaging technologies could prove advantageous to the New South Wales red meat industry and promote competitive access to important but geographically distant export markets.

Nevertheless, several key observations, outlined by Holman et al. (2018d), should be considered when exploring smart packaging responses to current industry challenges. For instance, the cost of implementation is a common hurdle for all such packaging responses. Costs may be reduced through improved economies of scale, device simplification and disposability. In terms of red meat, the smart packaging user should be clarified prior to its adoption so the connectivity and potential impacts of the user-interface on its retail performance are understood. In addition, legislative requirements for packaging differ between markets and may influence product access to the detriment of a continued or uninterrupted supply chain. Secondary effects of smart packaging must be clearly defined prior to usage: does a packaging solution that improves shelf-life at the expense of eating quality traits constitute a suitable technology? Lastly, many smart packaging options have been repurposed from other applications (e.g. medical and engineering fields, etc.) than for red meat packaging, creating an imperative that this latter application be tested *in situ* and compared to conventional packaging to establish a potential advantage (Holman et al., 2018e). From these reviews, we can recommend that the State red meat industry stakeholders consider packaging as part of a broader solution to managing current challenges. Further, these same stakeholders should ensure that the actual and economic contributions pertaining to *all* packaging are understood prior to adoption and implementation.

Effect of forage type on lamb productivity and product quality

New South Wales sheep producers that use extensive feeding systems would benefit from the identification of new forage types that have high protein and low cellulose and hemicellulose contents (Fraser and Rowarth, 1996). These characteristics promote animal growth rates, carcass weights and the efficient use of natural resources. However, past research has reported that some forages used as *novel feed-types* have had a detrimental effect on red meat organoleptic and shelf-life traits (De Brito et al., 2017b, Ponnampalam et al., 2016a).

To explore these outcomes, a total of sixty-two White Dorper lambs were finished on bladder clover, brassica, chicory + arrowleaf clover, lucerne + phalaris, or lucerne forages before being slaughtered and their *M. longissimus lumborum* and *M. adductor femoris* sampled (De Brito et al., 2016). These were sectioned and assigned to ageing periods (5, 12 or 40 days) where they were vacuum-packaged and held under refrigeration prior to testing. Lambs fed chicory + arrowleaf clover or lucerne forages had the highest carcass fat depth and dressing percentages. Bladder clover finishing resulted in increased glycogen content in the *M. longissimus lumborum*. However, no other meat quality trait, measured either within the laboratory or using an untrained consumer sensory panel, was observed (De Brito et al., 2016). The fatty acid profile and shelf-life metrics for these same samples were also analysed. It was found that chicory + arrowleaf clover resulted in the highest concentration of health claimable fatty acids, including the long-chain omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (De Brito et al., 2017a). Forage types with higher vitamin E levels showed lower lipid oxidation levels regardless of the ageing duration. Furthermore, sample retail colour stability was not influenced by forage type selection (De Brito et al., 2017a).

These findings were considered as a positive outcome, as animal productivity could be increased without any unfavourable effect on lamb-eating qualities and shelf-life. Moreover, forage selection could be used to improve the fatty acid profile and nutritional value of the lamb. This is pertinent as a high percentage of consumers have expressed a demand for lamb with higher levels of omega-3 fatty acids (62%) (Lamb et al., 2010). Even with this consumer trend, it should be noted that Australian lamb is yet to be overtly marketed in terms of its health claimable traits. Consequently, this information highlights the *niche* marketing potential available to New South Wales sheep producers in differentiating their product as a *healthy* option (Sinclair, 2007).

Identification of storage thresholds in frozen and chilled red meat

Frozen lamb and beef each represent a signification proportion of New South Wales exports to global markets, where geographic spread can make reaching them both expensive and time consuming (Malau-Aduli and Holman, 2014). Alternatively, red meat may be held *chilled* to enhance its eating quality and deliver a higher value product, albeit with a comparatively shorter period of preservation to the former method. Combining *chilled-then-frozen* storage could therefore permit quality enhancement associated with chilled storage before the frozen storage can be used to halt and preserve product appeal even after longer time periods (Coombs et al., 2017b). This could be valuable in managing product distribution and improving market access, matching production gluts more efficiently to instances of heightened demand, and promoting more cost-effective transportation.

To establish the effects of long-term chilled-then-frozen storage on red meat quality and safety traits, a total of 360 lamb loins and 48 beef loins were randomly taken from the boning rooms of commercial New South Wales abattoirs. These were vacuum-packaged (the beef first being divided into 4 equal portions); and held on-site for the duration of their assigned chilled storage durations (lamb: 0, 2, 4, 6 and 8 weeks | beef: 0, 2, 3 and 5 weeks). Samples were then frozen (if dictated and again on-site) before being transported to the 'Centre for Red Meat and Sheep Development: Meat Research Laboratory' where they were held for the duration of their assigned frozen storage periods (both: 0, 4, 8, 12, 24 and 52 weeks). Frozen storage holding temperatures were either –12 °C or –18 °C with freezers replicated. At the completion of their allocated storage treatment, each sample was tested for instrumental measures of sensory quality characteristics; display and shelf-life; microbial loading of key spoilage and safety organisms; lipid oxidation and fatty acid profiles; and protein degradation and oxidation markers (Holman et al., 2018c).

It was found that frozen holding temperature effects were negligible. This suggests that –12 °C could deliver comparable quality red meat to –18 °C across the storage periods examined in this study (Holman et al., 2017b). As –18 °C is conventionally used, if adopted, this result offers considerable energy-saving potential to the New South Wales red meat industry, reducing waste and environmental impacts because of improved long-term storage and transport efficiencies (e.g. slower shipping speeds, managing food wastage, etc.). That said, this observation should be applied using –12 °C as a "*maximum* temperature threshold" as industry would be best advised to use a lower frozen storage-holding temperature to allow a margin of error for unforeseen temperature interruptions.

Red meat quality parameters were shown to vary as a result of different chilled-then-frozen storage treatments, but when compared to existing consumer thresholds the variations were imperceptible (Holman et al., 2017a). Moreover, there was insufficient detection of key spoilage microbes in beef to allow for statistical analysis, possibly due to the hygienic and commercially representative LL[1] source, although variation in water activity, glycogen content, pH and other moisture parameters conducive to microbial proliferation were influenced by chilled-then-frozen storage (Holman et al., 2017a). Nevertheless, while lamb lactic acid bacteria, *Brochothrix thermosphacta* and *Enterobacteriaceae sp.* loads increased with *chilled* storage, the latter two types then declined as ensuing *frozen* storage duration continued (Coombs et al., 2017a). It should be noted that these microbial types are associated with meat spoilage rather than product safety.

Colour stability proved the exception as it became unacceptable earlier into retail display periods when either *chilled* or subsequent *frozen* storage periods were increased (Coombs et al., 2018a, Holman et al., 2017a). This is less of an issue while the end-product is destined for restaurants, food service or an additional value-adding process (e.g. sausages, mince, etc.), or when frozen product is retailed as is, instead of thawed prior to sale. Significantly, increased frozen storage periods produced beef fatty acid profile variations with unsaturated fatty acid levels declining as saturated fatty acid levels increased (Holman et al., 2018b). Polyunsaturated and health claimable fatty acid levels also tended to decline with increasing *chilled* storage period, albeit insignificant within the constraints of the experimental design (Holman et al., 2018b). This result needs to be verified as it has important ramifications for marketing New South Wales grass-fed beef as a *healthy* meal option. On analysis, other lipid oxidation markers, including peroxidase activity, TBARS and oxidation-reduction potential, reflected fatty acid profile variations (Coombs et al., 2018b). When compared against existing consumer thresholds, these suggest a perceptible increased marketability for red meat held under long-term frozen storage durations with the extent of the increase dependent on the preceding chilled storage period length.

Based on these observations, if New South Wales lamb and beef are effectively cold-chain managed so as to have low initial microbial loads, it can be held over long-term chilled-and-frozen storage. Permitting such storage durations would allow production and market demand variations to be stabilised without a reduction in tenderness, the development of rancidity or other adverse effects that contribute to a diminished perceived value (Coombs et al., 2016a, Coombs et al., 2016b). Such a management practice would counter claims of reduced quality due to the *chilled* product moving to a frozen state (e.g. accidentally frozen, etc.?) and then held for extended periods. Red meat display life or colour stability was found to deteriorate following either long-term chilled or frozen storage. Although this is not recommended, examples of *this practice* do exist in some export markets. Hence, it would be opportune to inform these markets of the likely negative effect on consumer acceptance and preferential purchase.

Optimising dark cutting and colour evaluation to predict beef carcass value

Dark cutting is problematic to the New South Wales beef industry and in an effort to discourage its prevalence, processors will generally discount and downgrade the value of these carcasses (McGilchrist et al., 2014). Their action is based on a preference

[1] The *longissimus lumborum* muscle, or loin. [Ed.]

for bright red beef and as dark cutting beef fails to match this criterion it is instead considered less fresh and of lower quality than normal beef. This fundamental difference results from dark cutting carcasses having insufficient glycogen reserves to drive *post-mortem* acidification which can impact on beef yield and quality characteristics.

Although different in other countries, in New South Wales, a trained operator will judge (grade) the exposed *loin surface* of a beef carcass as dark cutting or otherwise within the first 24 hours *post-mortem* (Ponnampalam et al., 2017). Common to all grading approaches is their use of a *single marker muscle* to grade and potentially discount the entire carcass. A comparison of three beef cuts from dark cutting and normal carcasses found that at least the bolar blade and potentially the forequarter of beef carcasses classified as dark cutting, did not reflect the negative attributes of the striploin and topside (Holman and Hopkins, 2019b). This outcome was supported by the differences in glycolytic derivate and pH declines observed between these same beef cuts (Holman, unpublished). Consequently, it is reasonable to conclude that components of a dark cutting beef carcass could be *salvaged* to regain a proportion of its undiscounted value. This could mitigate some of the associated economic and environmental impacts incurred from maybe not-so-inferior meat production.

Using a smart device app to improve objectivity of meat colour assessment

As previously stated, colour is an important factor in the evaluation and grading of beef carcasses, and conventional practice may involve subjective comparisons against standard references to gauge (dis)colouration. Due to the economic penalties associated with this assessment, it is important to be correct. The Nix Pro Color Sensor™ (NIX) is an inexpensive novel colorimeter that measures and transfers colorimetric data to a paired smart device (Nix Sensor Ltd., 2018). Red meat is not a homogenous substrate, so when testing the suitability of the NIX for beef analysis it was found that seven repeat measures are necessary to minimise response variation and contribute to improved precision (Holman et al., 2018a). When compared to another colorimeter, the NIX was found to capture colorimetric trends typical to display and ageing periods but had a lesser sensitivity than the widely used HunterLab MiniScan™. While this suggests a non-equivalency, the NIX remains a useful tool for red meat colour appraisal (Holman and Hopkins, 2019a). This notion was reaffirmed through its application in establishing a colorimetric threshold for distinguishing dark cutting beef carcasses. Based on the colour of the exposed *M. longissimus lumborum* (loin) surface between the 12–13th rib, carcasses found to have a chroma value equal to or greater than 30.5 were also dark cutters — permitting a degree of acceptable error (Holman et al., 2019). These findings are expected to be useful in providing the New South Wales red meat industry with an *objective* alternative to current methods of colour assessment: one that is simple, inexpensive and rapid. If adopted, this approach could prove valuable in reducing the costs associated with staff training and retention, ensuring against *subjective* misrepresentation, and *empowering* the industry to estimate other meat quality traits based on colorimetrics.

Accelerated ageing without compromising quality for beef

Consumers are willing to pay a premium for beef that is guaranteed as tender (Boleman et al., 1997, Feuz et al., 2004) and *ageing* beef provides a means by which New South Wales processors can capitalise on this opportunity. Currently, industry will routinely age beef for approximately two weeks to allow for enzymatic-mediated tenderisation. During this period the beef cannot be sold. This delay incurs many associated expenses (e.g. over-heads, storage requirements and lost opportunity) which could be reduced if the ageing procedure was to be accelerated. Past research has identified storage temperatures as important to ageing efficacy (Coombs et al., 2017b), these are often described as passive effects rather than those of an active management tool.

Recent research has aimed to establish time-temperature guidelines for industry to adopt for ageing beef so as to safely achieve improved beef quality within a reduced timeline. To test this, 320 beef M. *longissimus lumborum* portions were subjected to one of 72 unique temperature-time combinations (TTC) that were warmer and shorter than industry representative controls (~ 1 °C). From these it was found that beef can achieve comparable safety and eating quality, determined using both instrumental and untrained sensory panel analyses, in a shorter period of time to conventional practice if increased temperature is applied (Holman et al., 2018f, Kilgannon et al., 2019). However, based on current Australian safety guidelines (CSIRO, 1995), the authors instead recommended the adoption of shorter, cooler TTC that achieve the comparable outcomes (Kilgannon et al., 2019). These quality results were further supported by the analysis of volatile compounds released upon cooking and their known association with beef organoleptic characteristics (Kilgannon, unpublished). Research is ongoing into TTC effects on beef oxidative susceptibility and yield so that the commercial implications can be fully understood. Nonetheless, these findings have practical value within current industry safety and storage standards, and if adopted could minimise the resource requirement for producing high quality beef.

Conclusions

From these examples of research being undertaken in New South Wales, it is obvious that a scientific foundation is vital to uphold the wholesome reputation of New South Wales red meat across its global supply chain. Such research would improve red meat industry access to high value markets, achieve better information flow along their supply chains, advance lamb and beef eating quality traits in line with consumer expectations, and reduce associated production and processing costs. It should be noted that positive achievement in this sector extends well beyond the barbeque, but encompasses broad improvements to New South Wales economic and societal security. Recognition of these contributions should prompt a commitment that ensures continuous expert meat research capacity in New South Wales so that its red meat sector remains innovative and reactive to changing consumer demands. At least, the themes discussed above should encourage interest, conversation and contribution from the broader community into shaping the future of the red meat industry.

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