A STUDY INTO RED MEAT EATING QUALITY IN THE SCOTTISH MEAT SECTOR

WRITTEN FOR

Quality Meat Scotland

BY

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Contents

1. Introduction to the study

1.1. Key Study Elements

This report was commissioned to enable the improvement and marketing of red meat produced in Scotland under the Scotch Beef and Lamb brand and is intended to deliver:

1. A detailed analysis of red meat-eating quality research and frameworks or methods which have been implemented in Scotland, the UK and globally.

2. The delivery of benchmarking and an analysis of leading meat-eating quality driven production and processing systems across the world, followed by consideration of how they could potentially be applied to the Scottish red meat supply chain.

3. An evaluation of current red meat management systems in the UK and their ability to recognise meat-eating quality.

4. Identification and documentation of areas where eating quality can be improved in the Scottish red meat sector.

5. The production of recommendations for development in the Scottish red meat sector and how these changes can improve eating quality from Scottish red meat processors.

6. The use of the recommendations to produce short-, medium- and long-term actions and targets to enable the improvement of eating quality in the red meat sector in Scotland.

1.2. Relevant Outputs

a. A critical evaluation of all relevant models or methods of assessing and incentivising eating quality and their potential application within the red meat industry in Scotland.

b. A critical evaluation of the effectiveness of the existing EUROP grading system in the incentivisation of carcass quality and meat eating quality.

c. The production of recommendations for implementing and developing eating quality via the introduction of quality control measures that can be presented to red meat producers, processors and Scottish Government for discussion and possible implementation.

1.3. Overall Aim

The overall aim of the report is to identify practical methods which can be employed within the Scottish red meat sector to improve and guarantee quality, and which can be used to deliver competitive advantage in both the UK and export markets.

2. Methodology

2.1. *Tools Used During the Delivery of the Project*

A range of proven tools and methods were used to gather the required information, and are outlined below.

2.1.1. Tool 1: Desk-Based Research

As part of the delivery of the project we conducted a systematic literature review of red meat-eating quality research and existing frameworks in Scotland, the UK, and globally. We have utilised information from the scientific literature, including high impact peer-reviewed journals and grey literature. As part of the review, we defined the key focus areas including meat tenderness, juiciness, flavour, product life and nutritional content and referenced all sources.

All the information was then evaluated to determine its applicability to the red meat sector, with a particular focus on predicting or quantifying meat quality. The research reviewed various meat quality assessment systems, commercialisation models and the potential to encourage uptake within the industry. Within this, the cost of implementation and ease of use were considered, as well as the key attributes of each prediction model, the associated farmer payment models, and other enablers.

Opposing views in the literature have been represented and the findings analysed and discussed. Current gaps in knowledge have also been identified, forming a basis for potential future research.

2.1.2. Tool 2: Stakeholder Interviews

Widespread industry and stakeholder engagement was critical to the gathering of the information necessary to underpin the recommendations in the report. Stakeholder engagement included scientific institutes, representative organisations, commercial businesses and individual experts[1]. The following topics were discussed during these interviews:

- Currently available systems which can assess meat quality.
- Individual expert views on specific components of existing systems.
- Knowledge gaps in areas relating to meat quality assessment.
- Existing barriers to the delivery of an effective meat quality system within the Scottish red meat industry.
- Integration of a meat quality assessment system within the current red meat production chain in Scotland.
- An assessment of the financial investment required and the potential return from appropriate installation and management.
- Innovative technological solutions which are currently in the process of development and an assessment of potential methods of implementation in the future.

We used a structured, questionnaire-based approach which was completed during a discussion (rather than sequentially). This conversational approach ensured that all core information was obtained whilst enabling supplementary information to be collected. Core information was required from each stakeholder without restricting the flow of additional information.

2.1.3. Tool 3: SWOT and PESTLE Analysis

SWOT (Strengths, Weaknesses, Opportunities and Threats) and PESTLE (Political, Economic, Sociological, Technological, Legal and Environment) tools are strong methods of summarising and presenting information. We used the systems to deliver analyses of available technologies and systems which are currently available (or being developed) and to assess the impact and components of each system.

[1] Appendix One

2.1.4. Tool 4: Model Development

Impact models are an extremely useful tool in demonstrating broad impact as input values are altered. However, as explained later in this report, quantifying the true impact of each component is very difficult because of the number of factors involved and the fact that each component interacts with other ones. The scientific literature is unclear, although the Meat Standards Australia (MSA) work comes closest to indicating the impact of each component.

Instead of a true impact model, we have produced a model which describes the effect of each new technology or practice. It considered key enablers, barriers to scale-up, quality benefits (quantification of meat quality), economic benefits, further supply chain impacts (breeding and feeding), and attempted to rank the total value of each intervention to the Scottish red meat industry. Within the model development we considered all relationships (static and dynamic) affected by the implementation of meat quality assessment systems and comparison of this to existing grading systems in Scotland.

2.1.5. Tool 5: Case Study Review

As part of the project delivery, case studies were reviewed which quantified and presented the success of the previous interventions. Components of these case studies were drawn out to demonstrate good practice, and the necessary steps to implement appropriate systems within a commercial production chain were identified. We also tried to estimate impact at each level of the chain. The case studies were used to determine:

- Applicability of various systems to the Scottish red meat sector
- Long-term impact of different systems on the red meat sector in Scotland
- Barriers to implementation within the Scottish red meat industry
- Business models which could be implemented and methods of implementation
- Ease of implementation and use of any proposed system or methodology
- Potential cost benefit of different systems and interventions

3. Background

3.1. Context of the Scottish Red Meat Industry

Beef and lamb production have are highly important to the agricultural industry in Scotland with beef, sheep and dairy accounting for about 50% of the total agricultural output. Currently the cattle breeding herd consists of approximately 413,000 suckler cows and 174,000 dairy cows, producing approximately 390,000 prime beef animals per year in addition to cull cattle. The average number of suckler cows on a Scottish beef farm is currently around 48.5. Economic output is £849m for beef and £299m for sheep (QMS Red Meat Industry Profile 2021) representing 35% of Scottish agricultural output, with beef being the biggest single sector of the Scottish agricultural industry. Pork output is £139m in Scotland.

With self-sufficiency levels of 154% in beef and 220% in sheep, Scotland is dependent on selling product outside its national borders. The main consumer of Scotch beef and lamb is the UK, with 91% being sold there, 25% in Scotland and 66% in the rest of the UK.

Land type in Scotland is variable and includes lowland, upland, hill and mountain production. Approximately 55% of Scotland's agricultural land is used for upland sheep farming or mixed beef/sheep farming. Any outdoor pigs tend to be on flat, well-drained arable land.

A range of production systems are used to produce beef and lamb. These include birth to finish systems, calf to rearer to grower to finisher systems, suckler to store and store to finish systems, integrated rearing systems, 100% beef systems, 50% beef 50% dairy systems, 100% dairy systems and store lamb systems etc. With approximately 20,000 beef, sheep and dairy farms in Scotland there are significant challenges around monitoring of performance, transfer of knowledge or new practice, and, importantly, the management and measurement of eating quality.

On-farm practice is not standardised and any system to manage and record eating quality needs to account for this variation, and must be able to provide management recommendations for a range of systems to minimise the variation

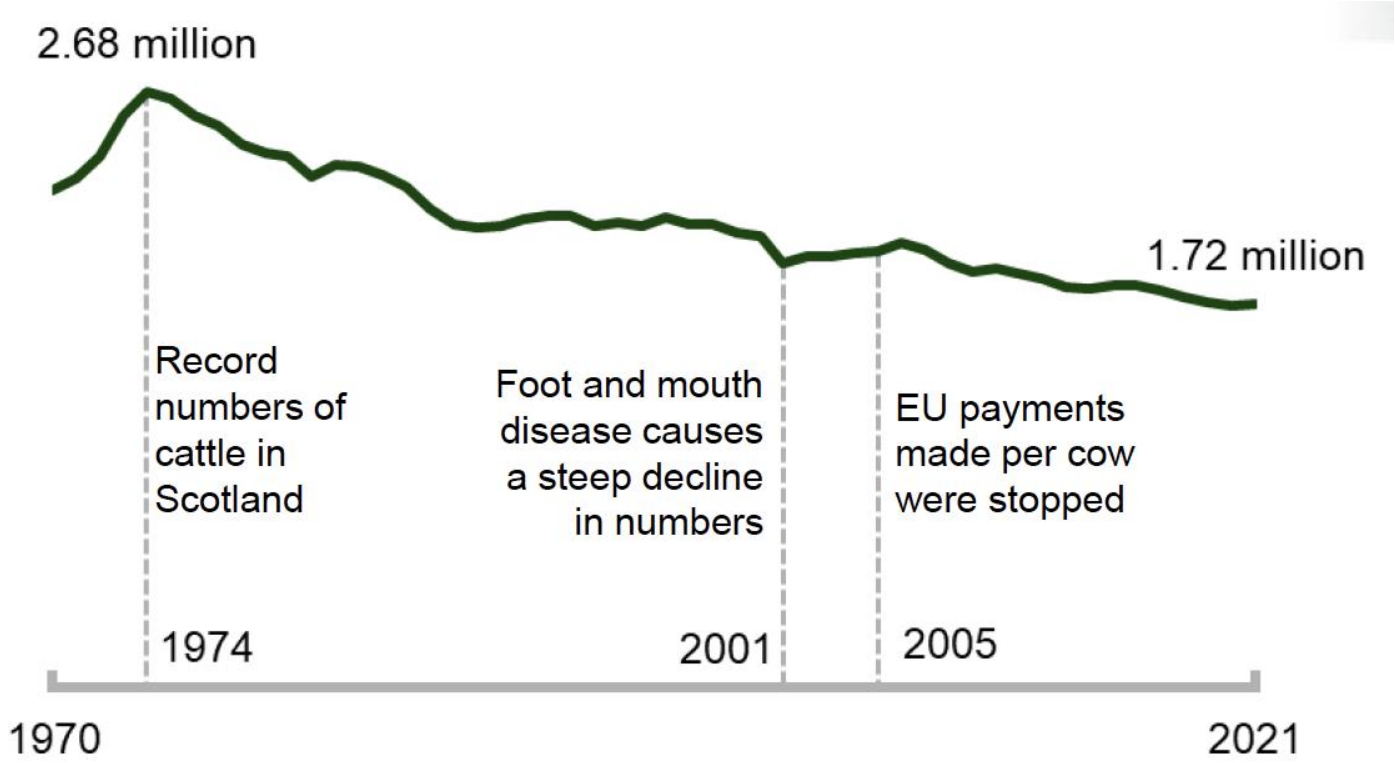
between the animals being presented at the abattoir. Any quality management system for Scotland will need to measure quality and provide recommendations for best practice at farm and in-factory.

3.1.1. Scottish Beef

A wide range of cattle breeds are used in Scotland, with Angus, Limousin, Charolais and Simmental being predominant. The use of a number of breeds is a direct consequence of the range of farming systems which exist in Scotland. The Scottish landscape is varied, with large tracts of lowland, upland and mountain land. The variability in land quality means that some breeds are more suitable than others. The land variability also means that the production and business models in Scotland vary, with some farmers not able to finish stock, instead selling it a weaning or store stage to other specialist finishers. This can mean that breeding farmers see their market as other farmers and not the end consumer, meaning that product is produced which could be better tuned to consumer needs.

This wide genetic base brings some product advantages, but it also leads to variability in animal performance and eating quality.

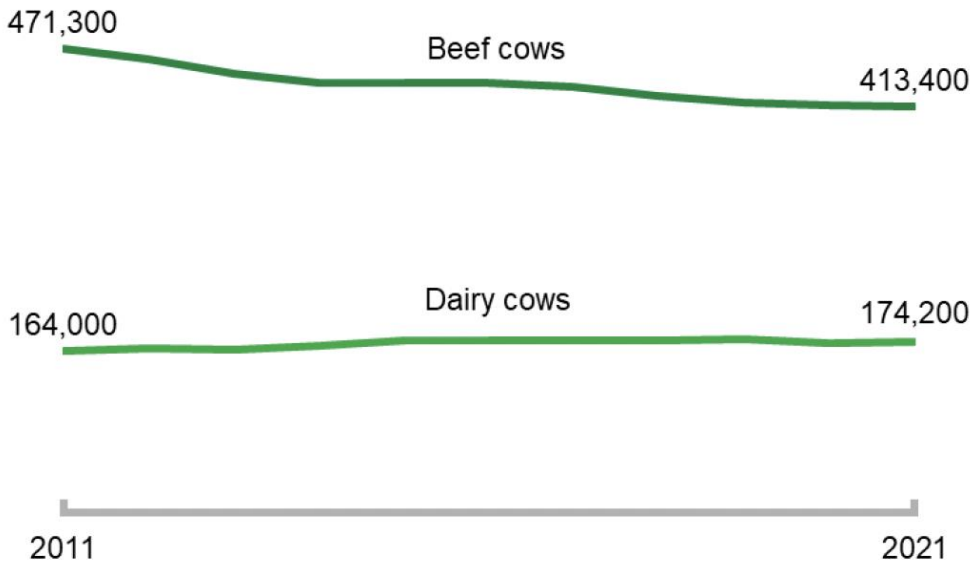
Figure 1: Decline in Cattle in Scotland (Scottish Agricultural Census: 2021)[2]



In 2021, there were 1.72 million cattle in Scotland, a rise of 1% on 2020 (which was the lowest count since 1957). Total cattle population in Scotland has been trending downwards since a peak in 1974 when there were 2.68 million cattle.

[2] Scottish Agricultural Census: June 2021 - gov.scot (www.gov.scot)

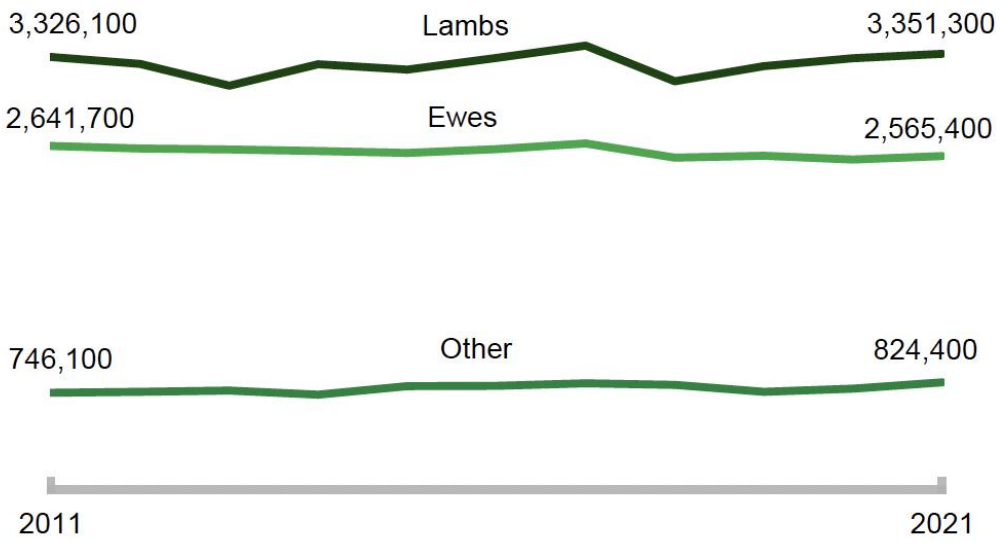
Figure 2: Decline in bovine breeding herd in Scotland (Scottish Agricultural Census 2021)[3]



3.1.2. Scottish Lamb

Scotland has a total of over 6.7 million sheep, with about 2.6 million breeding ewes and approximately 3.4 million slaughter lambs. However, not all these lambs are slaughtered in Scotland, with a high proportion transported to Northern England and Wales. Again, genetic variation is wide which leads to a range of animal performance and some variability in meat quality, although to a much lesser extent than in beef. The number of lambs has been rising slightly since a low in 2018.

Figure 3: Sheep and Lamb Numbers in Scotland (Scottish Agricultural Census: 2021)[4]

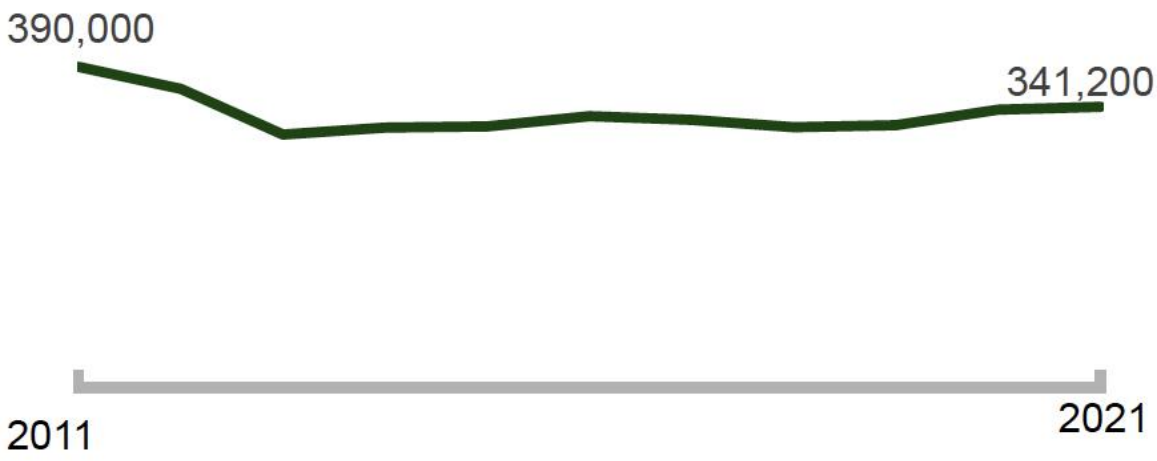


[3] The total cattle numbers hit sixty year low - Scottish Agricultural Census: June 2021 - gov.scot (www.gov.scot)
[4] The total cattle numbers hit sixty year low - Scottish Agricultural Census: June 2021 - gov.scot (www.gov.scot)

3.1.3. Scottish Pork

Pig farming represents about 3% of Scotland's agricultural output, with around 150 units holding almost all of the breeding sows. Production is split between indoor and outdoor with a focus on increasing productivity, growth performance, and yield in commercial pig units which has reduced total fat and intramuscular fat in the pig, leading to a reduction in eating quality. This has been addressed in some breeding strains which have been selected to increase meat tenderness. Pig numbers in Scotland have been strongly declining since 2003.

Figure 4: Decline in Pig Numbers in Scotland (Scottish Agricultural Census 2021[5])



3.2. Reputation for Red Meat Products

Scotland has a strong reputation for its beef and lamb products, is internationally recognised, and is one of the few primary agricultural brands to have achieved this. This has been recognised through the award of UK Protected Geographical Indication status (UKPGI) for Scotch Beef.

The marketing material around Scotch Beef PGI states that it is from specific animals which are sourced from selected Scottish farms who adopt best practice which includes animal welfare and natural production methods. This is true, but the brand makes no real claims around eating quality and does not include meaningful quality measures as an underpinning qualification for entry into the brand. Scotch Lamb also has PGI status and makes similar claims to that for Scotch Beef.

The Scottish red meat processing chain is dominated by a relatively small number of large businesses, although many small, local businesses are involved. Many companies supply products direct to the retailer or food service company, but there is a relatively large amount of product which is aggregated and sold though meat wholesalers.

In general, Scotch Beef (but not necessarily Scotch Lamb) attracts a premium over standard British meat, driven by a perception of increased quality. Prime sheep and cattle slaughter in Scotland is approximately 30,000 and 8,000 head per week respectively, with the majority of this produce (65%) going to the retail market.

3.3. Scotch Branding

Quality Meat Scotland manages the Scotch brand and engages a range of stakeholders in its use and promotion. Protection and development of the brand is crucial to ensure that it continues to engage consumer interest and to ensure that the attributes of the brand continually develop to meet emerging consumer need. QMS figures suggest that the brand (for beef) has delivered approximately £30-£40 per animal over the last 10 years – around £100-130

[5] Scottish Agricultural Census: June 2021 - gov.scot (www.gov.scot)

million in additional revenue. Evidence from Australia suggests that a well-implemented eating quality management system can add between 400 and 800 Australian dollars (£230 – £460) per head.

3.4. Consumer Demand

Repeated consumer surveys, and commercial experience with premium products, reveals a willingness to pay more for quality which is guaranteed[6]. If all opportunities could be accessed and maximised within the Scottish beef and lamb supply chain (especially in terms of quantifying and/or guaranteeing quality), the potential additional profit could run into several hundred pounds per beef animal.

These values would be driven through a careful approach to marketing a proven rise in product quality, as well as improved provenance. Raising quality will enable price rises to be achieved on steak cuts in particular, but also on roasting joints. Steak cuts represent from 12-14% of the carcass (depending on what product is used for what purpose), and raising the price on these cuts can release from £80-£200 per animal for guaranteed quality, depending on the market which is achieved. A study of prices achieved by different variants of the same product in the UK and other markets shows that there can be up to £18 per kg difference for the same product at different quality levels. It is acknowledged that this price difference is extreme, but it is being achieved in the marketplace.

Over half of the beef carcass is sold as mince. There are three main ways of raising price on mince, firstly through reducing fat levels, secondly through flavour alteration (grass fed vs concentrate) and finally through marketing the provenance of the product. The remainder of the carcass is generally used as roasting cuts and again quality and provenance attributes can be used to generate additional revenue over time, potentially contributing another £80-160 per animal. This is not easily achieved, but, with quality development over an extended period of time, it can be.

Raising sales value of lamb is much more challenging than for beef as lamb quality is generally better. However, the production of guaranteed quality lamb legs, chumps and loins could be used to increase product value by an estimated £3-£6 per kg for specific cuts. However, this is unlikely to be achieved across the whole market, but would represent around £20 per lamb.

The above value indicators show that the potential return on investment is much greater for beef than for lamb, and the majority of the initial focus on red meat development is more likely to be focused on the beef sector. Nevertheless, the whole red meat sector faces an urgent to change as the industry faces a range of threats and challenges which will impact ongoing economic sustainability. Any activity which can increase net profitability is important. The main challenges are:

1) **The demand for increased product quality and consistency.** Many studies show the existing variability in beef eating quality. This is a challenge to the industry because research by Northern Ireland's AFBI research institute demonstrates that one poor eating experience can mean that the consumer avoids purchasing it for up to three months, negatively impacting beef consumption. Other work shows that, where consistent quality can be demonstrated, product sales (and price) rise.

2) **The changing farm support system.** The Common Agricultural Policy reform will strongly impact the nature of beef and sheep farming and funding is likely to be reduced and repurposed. This change will force farmers to focus strongly on improving profitability, sustainability, inclusivity, productivity and innovation.

3) **The increasing environmental challenge.** Red meat production is under intense pressure because of its potential environmental impact and needs to set and meet a range of targets around the environment and climate change. The Scottish Government has declared a climate emergency and the Climate Change Bill was passed in October 2019 which is aimed at setting a pathway for Scotland to enable it to achieve net zero carbon emissions by 2040. The red meat industry must contribute to the meeting of these new climate change targets through demonstrating a reduction in carbon output. The more efficient the production system, the lower the environmental impact.

[6] Polkinghorne and Thompson, 2010

4) **Changing consumer demand.** Consumer purchasing habits are changing at an accelerating rate. Consumers are gradually moving towards the purchase of products which carry environmental and social benefits in addition to the traditional attributes of price, fat level, and appearance. This demand is also true for meat[7] and consumers will respond positively to meat products which demonstrate much higher eating quality and/or environmental benefits.

3.5. Carcass Grading and Payment

Payment for meat in Scotland is carried out on the basis of carcass yield. This is assessed through the long-established EUROP grading system. EUROP classification is based on the proportion of muscle and fat in the carcass, with the E,U,R,O,P letters being used to describe the level of muscularity of the animal and the numbers 1, 2, 3, 4 and 5 representing the proportion of fat in the carcass, with 1 being the lowest level of fat and 5 containing the highest level of fat.

The proportion of fat and muscle serve as a basis on which payment for the animal is made and pricing grids are set according to the weight and grade of the animal. Presently, around 85% of the market requires a conformation of E, U, R, and O with a fat classification of 2, 3 or 4, in both beef and lamb within predetermined weight ranges; however, the majority of these specifications have either no, or a very limited relationship to measurable meat quality based criteria and no specific quality cues are included. It is worth noting, however, that an increase in fat class is (within limits) usually associated with an increase in eating quality.

A proportion of beef grading is delivered through the use of automated equipment (usually through visual image analysis technology), but for the large majority of beef and almost all lamb carcass grading is carried out by a human grader. Human grading is recognised as having a relatively high level of variation between graders, and between factories.

3.6. Potential Industry Targets

The red meat processing sector is complex and the beef and lamb supply chain in Scotland is not fulfilling its considerable potential in terms of managing and developing eating quality. This is, to a large extent, because at farm level no practices are required to manage and/or enhance eating quality, and at processor level, payment for beef and lamb carcasses relies on an historical yield-based approach that is not focused on the delivery of a product that maximises customer satisfaction. This is also true of the pig industry in Scotland, where the main quality criteria is focused on the subcutaneous fat depth at the 10th rib.

Achieving the considerable potential of the Scottish red meat sector will be very difficult if quality is not measured and incentivised within the supply chain.

4.Eating Quality and the Consumer

4.1. Introduction

The weight of scientific and commercial literature demonstrates that flavour, juiciness, and succulence, along with tenderness, are the most important factors in meat palatability. Most alterations to these attributes occur during the pre-slaughter period or during further processing stages such as when muscle pieces are being cooked. The flavour of raw meat is bland, slightly metallic and serum like. It is only upon cooking that a series of thermally induced complex

[7] Sanchez-Sabate, Ruben, and Joan Sabaté. "Consumer Attitudes Towards Environmental Concerns of Meat Consumption: A Systematic Review." International journal of environmental research and public health vol. 16,7 1220. 5 Apr. 2019

reactions take place between the many different non-volatile compounds of the lean and fatty tissues[8]. Through a series of interactions and degradations of these components (peptides, amino acids, sugars, metabolites, nucleotides, lipids and components of lipid oxidation) the flavour of cooked meat is developed. Over one thousand volatile components of these reactions have been identified.

Historically, there have been considerable challenges to developing a consumer-based grading scheme, with a reluctance for active cooperation between countries and industry sectors within each country. A logical step would be the formation of a large-scale international collaborative effort to transform the meat industry to market quality-driven products within a value-based payment (VBP) system, growing demand while improving production efficiency.

It is important that Scotland retains its unique selling point (USP) with regard to eating quality, but this will be primarily driven through the application of on-the-ground good practice to improve quality, as research knowledge to improve quality is usually shared internationally relatively quickly.

Current meat marketing approaches all share the major defects of poor market transparency, imprecise product description at the point of sale, and invariably inadequate feedback of the consumer requirements back along the supply chain to the beef producer. This was identified many years ago by AHDB Industry Consulting in 2008 and very little has changed since.

The global nature of meat production and trading, the similarity between consumer response in all markets, and the high cost of research in a climate of scarce resources emphasises the desirability of pursuing a collaborative research agenda across institutions and countries. We have a global consumer and market in which competitiveness relative to alternate foodstuffs is far more important than competition between the meat industries of individual countries

It is our view that beef grading schemes need to be developed that focus on consumer requirements. This is essential to the development of a value-based payment (VBP) system.

4.2. Consumer Perception of Eating Quality of Red Meat

Consumer perception of meat and meat products is a critical issue for the red meat industry because it directly impacts on its profitability[9]. Quality cues such as tenderness and flavour are of immense importance to consumers at point of consumption. However, consumers find it difficult to decipher the quality of fresh meat and find it complex and difficult to define [10]. The multifactorial nature of meat quality, and the varied expectations of different consumers make it difficult to fully understand and predict specific consumer acceptability of a meat product.

Research has shown that consumers have difficulty selecting red meat of a consistent or reliable eating quality and this is a major factor in the global decline of beef consumption, particularly in developed countries[11].

There is an increasing demand from consumers for beef products which are more consistent and have guaranteed eating quality[12]. It is now well recognised that if a consumer has a negative eating experience they will drop out of the category for up to 12 weeks[13].

Research has clearly demonstrated that consumers are willing to pay more for guaranteed improved eating quality[14]. As part of the international consumer beef tasting sessions undertaken by Meat Standards Australia (MSA), consumer

[8] Calkins and Hodgen, 2007, Mottram, 1998
[9] Troy and Kerry, 2010
[10] Wim Verbeke, Ronald W. Ward, Consumer interest in information cues denoting quality, traceability and origin: An application of ordered probit models to beef labels, Food Quality and Preference, Volume 17, Issue 6, 2006, Pages 453-467
[11] Bonny et al., 2018
[12] Verbeke et al., 2010
[13] AHDB, 2018
[14] Polkinghorne and Thompson, 2010

willingness to pay for the various meat quality grades was examined. Assessment was recorded by each consumer recording the price per unit of weight in local currency ($/kg in Australia, $/lb in the USA, €/kg in Ireland and France, R/kg in South Africa and ¥/100 g in Japan) they believed was appropriate for each of the four quality descriptions (unsatisfactory, good every day, better than every day, and premium). The work clearly demonstrates that consumers associated increased price with increments in eating quality, and were willing to pay more for meat of better eating quality (Polkinghorne et al., 2008).

Science and technology has a valuable role in providing the means to enable the meat industry to improve consumer perception.

4.3. Customer (Retailer) Perception of the Eating Quality of Red Meat

As part of the research for this study, we interacted with a range of the key retail customers for red meat, including Sainsbury's, Coop and Marks and Spencer. The authors had previously discussed meat eating quality with almost all other key retailers in the UK. The degree of overlap between the comments of all retailers indicated that consumer feedback to each was very similar, and that the targets for red meat producers are clear and unlikely to change greatly. There are multiple factors which must be considered.

Generally:

1) The demand for high eating quality is increasing and will continue to do so. This is particularly the case for beef, less so for lamb, and, in general, eating quality is not considered to be quite as important for pork by many retail organisations (although some will disagree with this statement).

2) There is general acceptance that, in the future, individuals will eat a lower quantity of red meat, and as a result they will expect that the red meat they do eat will be of a higher eating quality. In other words, red meat is expected to become even more of a treat than it currently is, and that when it is consumed, it needs to meet quality expectations.

3) There is also general acceptance that global demand for red meat will continue to increase, which is likely to outstrip supply. This will continue to drive the price of red meat upwards, contributing to a lower volume of meat eating per person, but a higher expectation around eating quality as a result of the higher price paid.

4) The impact of political considerations on the type and volume of red meat produced is a concern to UK multiple retailers, with the higher prices for bought-in feed, and the highest prices ever seen for artificial fertiliser resulting in lower amounts of supplementary feed being purchased and much slower growth rates for beef cattle in particular, leading to shortages in supply.

Retailers' Point of View

1) Retailers would be supportive of a system which incentivised the improvement of eating quality.

2) Retailers indicated that the provision of quality guarantees (provided they are accurate and reliable), will result in increased sales.

3) Retailers also confirmed that consumers are prepared to pay extra for guaranteed quality, but that this has previously not really been possible in red meat. They indicated that the main quality indicators used in the sale of red meat are:
    a. **Breed**. Labels indicating the use of traditional breeds, and Aberdeen Angus in particular, are used to indicate meat which is of a higher quality. In general, this is true, but eating quality within one breed

can vary significantly and some beef from traditional breeds has lower eating quality that than from breeds which in theory should produce meat which is not as tender.

b. **Length of maturation period.** Consumers have become increasingly aware of the benefit of extended maturation periods, and meat is regularly sold with labels denominating 10 days, 14 days, 21 days, 28 days and even 35 days of maturation.
c. **Type of maturation period.** Dry ageing is sometimes used as an indicator of quality, although, in general, consumers are less aware of the quality impacts of wet versus dry ageing.
d. **Rearing method of the animal.** Rearing method is much less frequently used as an indicator of quality, but some smaller retailers (mainly outside the UK) have started to label beef as grass fed or grain fed.
e. **Tiering.** All retailers operate a tiering system for own-brand meat, usually including at least three levels [standard, better and best]. A price differential is implemented between the tiers, and often different cuts are used in different tiers.

4) Retailer representatives who understand the current payment system for cattle and sheep [the EUROP grid] did highlight its weaknesses and lack of incentivisation for eating quality improvement. In general they would be supportive of an industry change, but note that any replacement system must be well thought-through and reflect the true value of the animal.

5) All retailers were extremely supportive of the general concept of creating a system in Scotland which would holistically manage and assure the eating quality of red meat and reflect the true sales value of the meat back to the farmer.

4.4. Factors Affecting Consumer Perception of Eating Quality

4.4.1. Conformation of the carcass

Many within the industry often assume a well conformed carcass will also produce a high eating quality meat, but this is not necessarily the case. However, a consumer's perception of quality is influenced by the appearance of the meat and meat with low fat (intramuscular and rind/subcutaneous), a bright colour, and a high proportion of meat to fat. The preparation of the meat prior to sale can significantly impact the perception of quality through practices such as the removal of excess subcutaneous fat, correct portion size etc.

4.4.2. Hygiene

The hygiene of the meat does impact the perception of quality by the consumer. High microbial loads, besides being unsafe, increases the speed at which meat becomes rancid. Meat which turns rancid quickly is rightly judged to be of lower quality than normal meat. Even meat which is even partially rancid (or on-the-turn) will produce unusual and unpleasant flavours, negatively impacting the eating quality of the meat.

4.4.3. Nutritional Content

The proportion of lean tissue to fat impacts the overall nutritional content and has an effect both on the perception of the meat (too much fat is seen as negative) and the actual eating quality. Under blind taste testing conditions increased intramuscular fat up to about 7.3% is associated with improved liking of the meat[15], [16]

4.4.4. Provenance / Sustainability

There are several studies which show that information about the provenance, flavour, or attributes of a food, if presented before eating or drinking, will impact the overall perception of the quality of the product.

Effective communication of these attributes can therefore have a positive reaction, especially with more discerning consumers in the higher end market. Provenance information which is passed to the consumer could include:

- Breed of the animal
- Location of rearing
- Rearing type (extensive/intensive)
- Diet (grass/forage vs concentrate)
- Sustainability messaging

Some of the above factors (breed and diet) are known to have a direct impact on the quality of the meat and are covered in more detail elsewhere in this report, but the other factors either have no, or a very minimal effect, and their only benefit is to create a bias in the consumer's mind which encourages them to perceive the eating quality to be good.

4.4.5. Ethical Attributes of the Meat

Ethical attributes attributed to a meat product can, in the same way as a provenance story, influence a consumer to perceive meat as being of higher quality.

In general the ethical attributes associated with red meat are as follows;

[15] Frank, Damian et al. "Consumer Acceptability of Intramuscular Fat." Korean journal for food science of animal resources vol. 36,6 (2016): 699-708

[16] J. W. Savell and H. R. Cross. The Role of Fat in the Palatability of Beef, Pork, and Lamb

- **Farm assurance -** Consumers expect that the farms from which their meat comes from are of a high standard. This generally means that farm assurance is an essential component of the sales offering, but in reality consumers do not consider farm assurance until an ethical or safety issue appears. Nevertheless, messaging around the fact that farms are inspected and are up to standard can positively impact the perception of the quality of a meat product.

- **High animal welfare** - Consumers generally believe that all the food products they buy are from animals which are well treated and again, little consideration is given to this until an issue emerges.
    - This is generally the case for beef and lamb products because consumers perceive these animals as being reared outside under 'natural' conditions.
    - However, the perception of pork is impacted by the rearing method which is applied. Consumers are, in general, more concerned about the welfare of pork because of its intensive nature. The labelling of pork as 'High welfare' could potentially therefore influence consumers to perceive it as being of higher eating quality.

4.4.6. Appearance of Meat

The appearance of meat is one of the only criteria the consumer can base their purchase on, and is therefore highly important. The palatability (tenderness, texture, juiciness and flavour/odour) of a product is the criteria that a repeat purchase is based on.

Consumers use various evaluation criteria to evaluate fresh meat to decipher quality and value. They include intrinsic, physiological quality cues such as colour, visible fat, and exudate, and extrinsic quality cues such as price, product presentation, origin, and brand. These and others contribute to the consumers' "expected quality" which, in the case of meat, increases with consumers' perceived likeness of appearance, as well as freshness, but decreases with other factors as the amount of visible fat present in meat.

4.4.6.1. Meat Colour

- Consumers have been educated over many years that bright red is indicative of a high quality piece of meat. Consumers will discriminate negatively against meat that does not appear to match colour expectations and often discoloured meat (oxymyoglobin to metmyoglobin) cannot be sold unless it is significantly discounted or minced[17].
- Meat colour is dependent on the concentration and chemical state of the meat pigments, primarily myoglobin and haemoglobin, and on the physical characteristics of meat, such as its light scattering and absorbing properties[18].

4.4.6.2. Fat Content

- Excessive subcutaneous fat has a negative effect on purchasing decisions.
- Marbling is the visible fat present in the interfascicular spaces of a muscle and the architecture of the muscle influences the pattern of fat deposition such that looseness of the fascicular organisation generally parallels the quantity of interfascicular lipid present[19]. The intramuscular fat producing a marbling effect has been shown to affect flavour, juiciness, tenderness and visual characteristics of meat with increasing marbling in meat being linked to increased palatability[20].
- However, improvements in palatability with increasing fat percentage are not equal across all fat levels and fat levels exceeding 7.3% have been identified as too high by health-conscious consumers, consequently, meat with a fat content between 3 and 7.3% is generally considered acceptable[21].

[17] Sherbeck et al., 1995
[18] Kropf, 1993
[19] Kauffman & Marsh, 1987
[20] Miller, 2002
[21] Miller, 2002

4.4.6.3. Exudate

- One of the main quality attributes of fresh meat is its water-holding capacity because it influences consumer acceptance and the final weight of the product[22]. Any system prolonging the shelf-life of packed chilled meat will be subject to accumulation of exudates or drip. Exudate losses are exacerbated by cutting meat into smaller portions.

4.4.6.4. Packaging

- Modified Atmosphere Packaging (MAP) is one of the principal methods of maintaining and prolonging fresh meat colour as high oxygen concentrations within retail packs promotes the development of oxymyoglobin.
- However, in tandem with this process is the development of oxidative instability through muscle lipid degradation; consequently, leading to the development of undesirable flavours[23]. The breakdown products of lipid oxidation have been associated with the development of off-flavours and off-odours and more significantly, in the loss of fresh meat colour[24].

Consumers base their purchase choices on these perceived quality cues and it is essential that the meat industry (producers, processors and retailers) strive to enhance these cues in existing and new products. Furthermore, the industry must utilise the best scientific knowledge and technology to deliver this.

4.4.7. Post Purchase Organoleptic Assessment

The organoleptic quality of a product is the meat quality attribute which is most important to the consumer. Even if a product meets all the other attribute requirements expected of the consumer, if the eating experience is poor, they will be dissuaded from repurchasing the product.

In terms of the components of eating quality, beef texture is the most important, followed by juiciness, with flavour/odour least important. However, if there are high levels of abnormal flavour/odour it doesn't matter how tender and succulent the meat is, it will be perceived negatively.

For lamb, flavour is of more importance than tenderness when compared to beef because the variability in tenderness is lower[25]. The diet of the lamb is important because the flavour is heavily influenced by whether the lambs were fed on grass or on concentrate.

For pork, juiciness is important, followed by tenderness. Flavour tends to have a lower impact in pork [26].

4.4.8. Future Trends

Consumer perceptions are not fixed. However, how and in what direction consumer perceptions will change is difficult to predict because of the complex dynamic which drives the change. Most commentators do agree however, that on the basis that meat consumption per person will decrease, the quality demands for the meat that is eaten are likely to increase, particularly if, as expected, meat becomes more expensive.

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[22] Den Hertog-Meischke et al., 1997
[23] Estevez and Cava, 2004, Rhee and Ziprin, 1987
[24] Faustman, Chan, Lynch, & Joo, 1996
[25] Miller, Rhonda. "Drivers of Consumer Liking for Beef, Pork, and Lamb: A Review." Foods (Basel, Switzerland) vol. 9,4 428. 3 Apr. 2020
[26] Aaslyng, Margit & Oksama, Marjatta & Olsen, Eli & Bejerholm, Camilla & Baltzer, Maiken & Andersen, Grethe & Bredie, Wender & Byrne, Derek & Gabrielsen, Gorm. (2007). The impact of sensory quality of pork on consumer preference. Meat science. 76. 61-73

Recently the term 'quality' has become multifaceted, and in the minds of many consumers includes much more than safety, sensory and shelf-life aspects, and now includes other associated benefits such as nutritional content and impact on overall well-being and health.

Consumer perceptions therefore are dynamic and ongoing monitoring is required. It is worth noting however that there are often differences between what consumers perceive and their behaviour in response to what they know.

However, the industry faces other challenges in terms of consumer perception, especially in terms of convenience. This highlights the need for the industry to not only deliver on expected quality, but to deliver that to the consumer in new and innovating ways. The application of science and technology is critical in augmenting consumer perception of meat quality and delivering future market growth.

4.5. Processor views

The authors of the report have regular and ongoing contact with representatives of a range of red meat processors, and broadly their views have not changed. There are four main factors which are of primary concern:

1) Ongoing supply of beef and lamb
2) Price of beef and lamb to the consumer
3) Carbon and environmental impact of beef, lamb and pork
4) Eating quality of beef in particular, but also for lamb and pork.

With specific reference to eating quality, processors recognise that there is a genuine challenge. They acknowledge that variability in quality carries significant economic cost, through product returns and, more significantly, through dissuading consumers from purchasing meat on the basis of previously poor experience.

They also acknowledge that action can be taken within each processing facility to enhance (or at least preserve) good eating quality characteristics. It is also accepted that selection criteria can be applied to stock to identify premium products – although it is known that despite implementation of all these factors much variability still remains.

Two concerns are paramount. Firstly, there is concern that if poor quality product is identified, it will be difficult to sell, and this could be damaging within what is a low margin sector. Secondly, and perhaps more important, is that it is believed (probably correctly) by processors that much of the variability which is observed in eating quality is a result of variability at farm level. The view is that addressing the farm variability challenge is very difficult. Many expressed the view that it can be sorted within specific (and narrow) supply chains, particularly integrated production systems, but it is almost impossible to sort across all farms within the wider supply chain. Where processors are attempting to improve quality, this is generally being done in conjunction with Farm Assurance bolt-ons in addition to considerable farm engagement (which is challenging and time consuming).

5. Managing Eating Quality

5.1. Introduction

The red meat sector faces a range of challenges, especially around the environmental cost of production, management of animal welfare, reduction of food waste, increased competition from cheaper meats, the growth of non-meat alternatives, as well as the need to raise eating quality and improve its consistency.

The control of meat-eating quality is a persistent challenge. A very large body of academic and commercial research has revealed a large variation in the quality and consistency of red meat which is served to consumers in the UK (the main market for Scottish beef). It is therefore extremely important that when consumers decide to purchase red meat, their eating experience is good.

Research has shown that consumers have difficulty selecting red meat of a consistent or reliable eating quality. This is a major factor in the global decline of beef consumption, especially in developed countries[27]. Within the UK and Europe, beef and lamb grading systems rank individual carcasses according to carcass conformation as a predictor of yield, and fat class, both of which are mostly based on subjective assessment. However, when relating this to consumer sensory scores, these grading methods are poor at discriminating on eating quality when assessed against consumer taste panels[28].

Within the UK beef supply chain especially, variability in meat quality is high, resulting in low levels of consumer satisfaction. Large degrees of variability in age of slaughter, carcass weight and fat classification produce an inconsistent product, increasing the probability of a bad eating experience. According to research by AFBI in Northern Ireland, one bad eating experience can prevent consumers repeat buying for up to three months. Currently in the UK there is no commercially implemented system which enables large scale differentiation of meat on the basis of measured eating quality.

Any quality management system must be designed with implementation at farm and factory practice in mind. Widespread implementation demands that any system must contain a range of easy-to-understand practices which can be used on-farm and which can be verified and reported on to enable payment for best practice. A quality management system must deliver feedback to farm managers, and should enable incentivisation based on the final eating quality of their animals. In general, the most effective way to drive performance at a farm level is through a mixture of financial incentive and penalty.

Many of the changes which could be made to improve eating quality could also substantially benefit environmental performance and these 'win-win' changes are critically important. At a farm level it seems highly likely that any quality management system would have to be verified through QMS Farm Assurance, with quality-improving inputs being required and outcomes measured wherever possible. One of the outputs of this report is a menu of options to improve and/or guarantee eating quality which can be implemented on-farm and then confirmed by farm assurance.

[27] Bonny *et al.*, 2018
[28] Polkinghorne and Thompson, 2010

5.2. Factors for consideration when managing eating quality

5.2.1. Intrinsic Factors;

- Genetics of the animal (which strongly impacts the other components which impact eating quality)
- Muscle fibre type and thickness
- Concentration of collagen bonds
- Breed
- Gender
- Age
- Pre-slaughter nutrition
- Animal management impacting lifetime welfare, etc. (Lawrie, 1992).
- Diet which the animal was offered

5.2.2. Extrinsic Factors

- Method of carcass suspension
- Electrical stimulation regime
- Carcass chilling regime
- Ageing period for the meat
- Packaging/storage of the meat
- The cooking method (SEERAD report, 2004).

5.2.3. Control Points for Each Factor

Each of the above factors is within the control of someone within the production and consumption chain. Our calculations suggest that there could potentially be twenty different people influencing the final eating quality of any particular piece of meat, from those who are making the decisions (meat specification, chilling region etc.) through to those who carry out the actions (e.g. meat butchery or cooking).

This means that management of meat-eating quality within the red meat chain is very difficult. Achieving ideal eating quality needs buy-in from multiple individuals who all need to understand and implement best practice within their component of food chain.

Approximately 30% of beef quality is affected by what happens on farm, and about 70% is under the control of the processing sector. However, as processing practice becomes increasingly standardised, so the proportional importance of farm practice increases. Best eating quality is a composite of control throughout all aspects of the production chain.

The literature suggests that, for lamb, more of the responsibility for managing eating quality lies at farm level, with estimates of around 70% being generally accepted, although the literature is not at all clear on this. Diet is one of the most significant factors influencing consumer liking of lamb, and this is obviously totally within the control of the farm manager.

Similarly to lamb, the majority of eating quality for pork is influenced at farm level. Genetics and fat content of pork are key determinants, and are again under the control of the farmer.

5.2.4. Factors under the control of the farm

Factors which can be controlled on the farm are:

1. Genetics and breed of the animal
2. Gender (sexed semen or selection of specific animals for specific sales outlets)
3. Pre-slaughter nutrition
4. Animal management
5. Animal diet

6. Age at slaughter
7. Conformation class at slaughter (relatively minimal control)
8. Fat class at slaughter
9. Pre-slaughter handling and transport
10. Pre-slaughter diet and access to water

5.2.5. Factors under the control of the processing plant

Factors which can be controlled or influenced by the processor include:

1. Lairaging conditions and management
2. Slaughter method (captive bolt vs electrical)
3. Method of carcass suspension (hip vs Achilles)
4. Electrical stimulation regime (none, low voltage, medium voltage, high voltage, smart-stimulation/variable)
5. Carcass chilling regime (rapid/medium/slow)
6. Ageing period for the meat (none, through to 35 days)
7. Cut selection (selecting and classifying meat according to its cut)
8. Packaging of the meat (with different packaging types altering the rate of maturation, the oxygen fed re-binding of muscle fibres and the rate of bacterial growth).
9. Hygiene of the process (which impacts the rate of bacterial growth on the meat and the formation of off-flavours).

5.2.6. Factors outside the control of the farm or the processor

Several other factors influence the eating quality of meat, but these remain outside the control of farmers and meat processors. These include the following:

1. Maintenance of cold chain after meat reaches the distribution depot. The breaking of the cold chain tends to happen most frequently once it has left the control of the processing plant
2. Length of time the food product is stored for before it is consumed
3. Cooking method
4. Cooking temperature
5. Cooking time
6. Method of cooking

Information can be provided to the consumer to influence how they cook and use the product. The food processor can, to some extent, influence this through the provision of effective labelling and other sources of information.

5.3. Managing and Controlling Eating Quality

In order to produce meat of consistently high eating quality, a thorough understanding of the important factors which influence quality is imperative. Results from focused research into meat eating quality revealed that tenderness, juiciness, flavour and overall palatability remain the most sought-after attributes by consumers, with tenderness being the most important[29]. Evidence clearly shows that customers are willing to pay more for guaranteed tenderness, but unfortunately up to 20% of steaks sold to consumers are unacceptably tough[30].

The literature is clear that there is no silver bullet to manage eating quality for any of the species under consideration. As a result, a step by step, holistic approach to quality management is required, with good eating quality being provided through the aggregation of multiple components across both farm and factory practice.

This will involve building quality management specifications for each species which indicate the practices which must be combined to match quality to the expectations of the consumer.

[29] Miller, Carr, Ramsey, Crockett, & Hoover, 2001
[30] Miller, 2002

The creation of these specifications is challenging and, in all likelihood will continue to develop as scientific understanding rises.

However, the most challenging aspect of managing eating quality is around assuring that the specified good practice has actually occurred. This is true at both farm and factory level, but the sheer number of farms involved in the production chain presents significant difficulties which must be addressed if an effective quality management system is to be delivered.

5.3.1. Managing Eating Quality at Farm Level

Ensuring consistently high meat quality starts on the farm. Meat quality can be influenced by many different factors on the farm and understanding these offers the opportunity to improve the eating quality and consistency of the end product. Optimising the important factors at farm and processing level can vastly improve meat eating quality. These factors are outlined below:

5.3.1.1. Genetics of the Animal

The genetics of the animal are a key determinant of eating quality because they significantly influence a range of key components. Genetics interact with the animal's environment to impact phenotype (although the relationship is not yet fully understood). Genetics impact:

- Carcass muscle structure
- Type of muscle fibres
- Speed of growth of the animal
- Temperament of the animal
    - Good temperament is associated with improved meat quality, productive performance, and ease of transport. Better temperament is genetically correlated with improved tenderness[31].
    - Animals with poor temperament are more likely to produce progeny with beef of unacceptable eating quality as temperament is heritable.
- Overall fat content of the meat
- Intramuscular fat content
- Calpains
    - One of the important determinants of meat tenderness are the extent of proteolysis on key structural proteins and the degree of shortening of the muscle fibres. Most evidence points to the calpains as the main proteomes (proteins) involved in post-mortem tenderisation[32].

Implementing control of animal genetics on-farm is fraught with difficulty for a number of reasons:

1. Some farmers are more interested in the appearance of the animal rather than the attributes of the meat produced and will resist changes which could impact this. These farmers are generally focused on sales of breeding stock through shows, which unfortunately have a disproportionate influence on farmer behaviour, specifically around what is considered to be the optimal animal.

   There is a need to change the emphasis and effects of shows and key sales, moving assesment from the appearance of the animal toward assessment of genetic factors (such as growth, feed conversion efficiency, and eventually eating quality etc.) and performance/productivity factors such as weight for age, as well as measures which are appropriate for the consumer such as back length. Shows are in a position to nudge the industry towards productivity and profitability and have an important role to play.

2. A proportion of the beef animals finished in Scotland originate from the dairy herd, and the focus of the dairy farmer is almost entirely on the production of milk, and beef quality will not be a consideration – although, interestingly, work by AFBI and others in the Australian and European industries has

[31] Kadel et al., 2006
[32] Dransfield, 1993

demonstrated that (probably due to the higher levels of intramuscular fat in dairy breeds), the eating quality of dairy bred animals is good, and close to that achieved by traditional beef breeds.

It is also highly important for the Scottish beef industry to understand that, in contrast to what is often claimed, beef from suckler herds is often not as high quality as for dairy cross animals (or pure dairy steers). This is concerning and emphasises the need for beef suckler breeders to target increased eating quality within their breeding programmes.

5.3.1.2. Sex of the Animal

Cattle

In general, it is accepted in the literature that heifers tend to be more tender than steers, which are more tender than bulls. This is not always true and there is significant overlap, but, over a large group of animals it does hold true. Overall, steer and heifer beef delivers consistently high quality, whereas beef from bulls tends to be associated with a higher incidence of toughness and other eating quality problems.

There is a strong management/sex interaction and it is known that good eating quality can be obtained, even for bulls, provided that the management is appropriate to the animal.

Sheep

In general there is less impact of the sex of the lamb on overall eating quality, provided that entire male lambs are slaughtered before six months of age. Management of this is relatively simple, with rules able to be introduced around the age of the lamb which can be presented. Most procurement officers are aware of the lambing period which is operated by each farm which supplies the processor and can provide guidance around acceptable supply period from each farm.

Pigs

Flavour taint can emerge for entire male pigs above a certain age. In general this can be managed through putting a weight limit on entire male pigs at around 105kg liveweight.

Providing quality assurance around sex of the animal from which the meat came

The use of the sex of the animal to control quality is already established practice across a range of different species and different retail outlets. We suggest that animal sex is used as one component in an overall plan for improvement of quality in the sector.

5.3.1.3. Diet of the animal

Consistency of flavour is important to the consumer when purchasing beef. Fat is crucial for flavour as a minimum level of 30mg/kg (3%) is required to achieve acceptable eating quality for beef[33]. Tenderness of beef is even more important than flavour, and the rapid growth of animals is closely associated with their speed of growth.

Fatty acid composition is heavily influenced by diet and has a significant influence on juiciness and flavour. A diet with a high proportion of grass and forage will have a substantially different flavour to beef from animals which have been fed on cereals. Consumer preferences differ, with some preferring grass fed flavours and others preferring concentrate fed flavours.

In general, lamb flavour is more heavily influenced by diet than beef or pork, but the demand for grass fed beef is also growing. It is worth noting that at least one retailer has already launched a grass fed beef range (Lidl) in the UK and that a number of others are giving consideration to this option. The beef is being marketed on the basis of

[33] Enser et al., 2001

flavour/taste, 'naturalness', and the perception of high animal welfare, and should it prove commercially successful, it will draw a link in the consumer's mind between 'quality' and 'grass fed'.

It is worth noting the growing success of the Pasture for Life brand created by the Pasture Fed Livestock Association. They champion the benefits of grass fed livestock production, emphasising taste, health benefits, biodiversity benefits, welfare benefits etc., and have produced a clear set of standards to define what pasture production is and how farms can comply. Essentially the standards prohibit any form of cereal feeding, root crops or co-products, although root crops can be grazed. The standards also require that animals graze a range of species and monocultures are not permitted. Permitted winter feeding includes grass silage, arable silage or wholecrop.

All indications suggest that, from a global perspective, the demand for grass fed animal products is going to rise substantially in the future, and Scotland can be in a good position to exploit this.

Providing quality assurance around diet

Providing assurance around the diet of the animal presents some challenges, and potential solutions are as follows:

1) Inspection as part of the Farm Assurance audit, with a focus on the grassland available to the farm, the amount of forage made or bought in, the amount of cereals grown or bought in.
2) Self-declarations can be completed by the farmer which can be checked during Farm Assurance.
3) Spot analysis of the fatty acid (VFA) composition of the fat of the animal. Profiling of the VFAs will provide assurance around the type of diet on which the animal has been fed

We suggest that assurance around the diet of the animal should be used as one component in an overall quality management plan, but this is particularly important in the case of lamb.

5.3.1.4. Age at Slaughter

Collagen fibrils and fibres are arranged in intramuscular tissue during the development of muscle. The collagen becomes progressively tougher, more rigid and less easily denatured over time, leading to increased toughness as the animals age. This is more pronounced in entire male animals (Bailey, 1985[34]). Bonny et al. (2016)[35] investigated the age of the animal and its impact on eating quality. They found no relationship for animals that are less than three years old. However, the anecdotal evidence around the effect of age is strong, and it is another control factor which should be considered.

Providing assurance around age at slaughter

Providing assurance around the age of cattle is generally not difficult as the date of birth of beef animals is recorded on an electronic database and can be checked at slaughter.

Assurance around the age of lambs is slightly more difficult, but the lambing period is relatively easy to obtain and the age of the animal is relatively easy to ascertain.

Assurance around the age of pigs is more easily managed by monitoring the weight of the animal.

We suggest that age at slaughter is used as part of a quality management system, with limits being applied. These limits will be different for different species, sex and management methods.

[34] AJ Bailey - Journal of Animal Science, 1985

[35] SPF Bonny, JF Hocquette, DW Pethick, LJ Farmer… - Animal, 2016: The variation in the eating quality of beef from different sexes and breed classes cannot be completely explained by carcass measurements.

5.3.1.5. Fat Level at Slaughter

Intramuscular fat produces a marbling effect which has been shown to affect flavour, juiciness, tenderness and visual characteristics of meat, with increasing marbling in meat being linked to increased palatability; however, fat levels above 7.3% are considered too high. Meat with a fat content between 3 and 7.3% is generally considered acceptable[36].

Marbling or intramuscular fat (IMF) is fat that is stored in adipose tissue between muscle fibre bundles within the muscles. IMF is beneficial to flavour, taste and juiciness. IMF develops during growth, together with muscle fibres, and continues to increase after muscle development is complete.

The quantity of intramuscular fat or the degree of marbling is affected by many factors, namely; animal breed, slaughter weight[37], feeding strategy[38], and growth rate[39].

Providing assurance around fat level at slaughter

The carcass fat levels are relatively easy to ascertain at slaughter, either by visual analysis of the carcass (beef and lamb) or by measurement of fat depths in pork.

Intramuscular fat has more influence on eating quality than simple fat level, but is more difficult to determine. For cattle however, IMF can be measured at the cut face as the carcass is quartered. Simple visual assessments can be carried out against a grading card, or, more accurate methods (involving visual image analysis tools such as Hyperspectral Analysis) can be used.

Identification of fat levels and intramuscular fat levels can be determined relatively easily. The more major challenge is the procurement and selection of enough animals to provide a critical mass of product to target specific markets.

5.3.1.6. Pre-slaughter Handling

Pre-slaughter handling of animals can heavily influence eating quality. However, good pre-slaughter handling can only maintain the quality which already exists, it does not enhance it. Poor pre-slaughter handing can only reduce quality.

High stress for animals prior to slaughter depletes muscle glycogen, leading to high pH immediately after slaughter. This is associated with a number of quality problems including Pale, Soft and Exudative (PSE) and Dark, Firm and Dry (DFD) meat, with associated shelf-life challenges.

Cattle and pigs are susceptible to poor pre-slaughter handling and, within this, entire male animals are particularly susceptible.

Providing quality assurance around pre-slaughter handling

Providing quality assurance around pre-slaughter handling is difficult because it straddles both farm level and factory level. Generally farmers separate animals for slaughter well in advance of collection, so animals can be standing about, mixed with other unfamiliar animals, without access to food or water.

Animals can then be transported for a considerable distance for 8-12 hours (in some cases) before being placed in a lairage, where they can again be mixed with unfamiliar animals and stand without access to food for several hours prior to slaughter.

Protocols can be written to specify exactly how animals should be handled pre-slaughter, but without an auditor being present at each of these stages it is difficult to provide guarantees around this stage.

[36] Miller, 2002
[37] Candek-Potokar et al., 1999
[38] Blanchard et al., 1999
[39] Therkildsen et al., 2002

5.3.1.7. Transport

Transportation is considered a major stressor for farm animals and might have deleterious effects on health, well-being, and product quality. Therefore minimising travel distance will improve meat quality.[40]

Extended animal transport is associated with muscle glycogen depletion and "dark-cutting" beef. Other effects of transport on meat quality demonstrated by research include increased toughness and decreased palatability.[41]

Providing quality assurance around transport

Transport is easier to manage and provide assurance around than the other pre-slaughter handling components. Essentially, however, it has to be managed by the processor and the provision of assurance around this can really only be conducted through the audit of transport records during factory inspection.

[40] von Borell, 2001
[41] Tarrant and Grandin, 2000

5.4. Eating Quality Management at Factory Level

The processing sector has very rigid but robust systems for the processing and conversion of muscle to meat. To supply Scotch Beef and Lamb, meat processors have to be part of the QMS Processor Assurance Scheme, and it is this which is most likely to be used as the vehicle for delivery of a quality management system. Provided that a workable system can be identified, it can be included as a requirement for any product which uses the Scotch Beef or Lamb certification.

As identified elsewhere in this report, a high proportion of Scotch Beef and Lamb ends up in retail stores. Because this enters stores as Scotch Beef or Lamb, the retailers are able to monitor customer satisfaction of these lines. Because Scotch product is more expensive, it has to deliver against a quality agenda to hold on to (or grow) its market. This quality advantage must be detectable, beyond that which is conferred on the product by its Scotch branding.

In addition to the proportion of beef and lamb sold into retail stores, a significant volume of product is sold outside the UK. It is the intention of the industry to increase this level of export and, in reality, there will be three main attributes on which it will be marketed. In no particular order these are: 1) The Scottish provenance and integrity; 2) The environmental and landscape credentials, and; 3) the eating quality of the meat. Each of these three factors will interact with each other to encourage initial and repeat purchasing.

The key target export markets for Scotch Beef include Belgium, Netherlands, Germany, Sweden and Denmark within the EU and outside of that region, Hong Kong and Canada.

A range of meat processing techniques are employed in Scotland which have a strong impact on meat quality. Factors within the slaughter process which are under the control of the processor include;

5.4.1. Lairage time

The time spent in the lairage is crucial, particularly when considering bulls which should be moved directly from transport to slaughter as acute stress can have a negative impact on meat quality. Tarrant and Grandin (2000) stated that the animal behaviour most closely associated with muscle glycogen depletion and “dark-cutting” beef is mounting activity; this behaviour is stimulated by social regrouping caused by mixing unfamiliar cattle.

5.4.2. Electrical Stimulation

The primary reason for the use of Electrical Stimulation (ES) in the meat industry is to allow rapid chilling of carcasses without the risk of cold-shortening; however, rapid chilling isn’t practised within the industry now as often as it was in the past.

Electrical stimulation uses up the glycogen in the muscles immediately after slaughter, which is converted to lactic acid, causing a fall in pH. The target pH-temperature decline during rigor mortis is to achieve a pH of 6 between 35^{o}C and 15^{o}C.

Two types of electrical stimulation are in common use across the world; Low Voltage Electrical Stimulation (LVES) and High Voltage Electrical stimulation (HVES).

HVES is more difficult to manage and is the more likely of the two systems to cause heat shortening in beef.

LVES is easier implemented in beef and more effective, and is commonly used to immobilise beef carcasses while the hide is removed.

A clearer understanding of the optimum pH/temperature environment throughout the carcass would aid greater precision in the application of / need for electrical stimulation.

5.4.3. Carcass chilling regime

In relation to beef carcasses, the pH-temperature decline post-mortem is critical in determining the tenderness / toughness of meat. Given the nature of the carcass; muscle size and location, pH-temperature declines are going to vary greatly throughout a carcass due to variation in biochemical profiles which will ultimately result in meat of highly variable eating quality.

The rate of pH fall also varies from animal to animal depending on pre-slaughter experience and muscle glycogen levels[42], and the temperature distribution within a chilling system can also vary considerably. Both these factors greatly affect the pH-temperature decline, leading to considerable variability in pH-temperature decline profiles.

Shortened muscle fibres produce tough meat. This can occur when early post-mortem variables of pH, temperature and time interact in such a manner as to induce cold-shortening. Pre-rigor muscle shortens on exposure to temperatures below about 10 °C[43].

5.4.4. Hanging Method

The hanging position of the carcass can impact the eating quality of specific cuts in the carcass, while at the same time causing additional toughness in some other less valuable cuts.

Carcasses are normally suspended by the Achilles tendon, but as an alternative, the hip bone (tenderstretch) can be used. This has the effect of causing the leg to fall downwards, stretching the muscles along the back and causing up to a 20% increase in tenderness.

It does have the effect of causing a reduction in yield of striploin by one steak width (3-5% of the total) due to the 'folding' effect of hip suspension.

5.4.5. Maturation Method

5.4.5.1. Dry Ageing

The dry ageing process normally involves the storage of beef at 0–4 °C, uncovered, for 3–5 weeks under a relative humidity of between 75 and 80% in a controlled air flow environment.

Dry ageing can see some 15% of the carcass being lost (up to 60kg on a typical beef carcass). At an average of around £4 per kg this can cost around £240.

Holding additional carcasses in a factory setting comes at an energy and space cost, which some estimate at £5-7 per carcass per day. Thus holding a carcass for 20 days costs between £100 and £140 in energy and space costs.

5.4.5.2. Wet Ageing

Wet ageing of meat takes place in vacuum pack. Using this method, the enzymes still have time to tenderize the meat enough to make it acceptable, and the method has the advantage that there is no weight loss in the meat due to moisture loss. Wet ageing also costs less for the manufacturer than dry ageing since the meat doesn't need to be stored or monitored, ultimately resulting in a lower consumer cost.

However, some argue that wet ageing does not produce the same complex flavours that dry ageing does, but the literature is divided on differences in perceived eating quality between wet and dry ageing. It is worth noting that the term 'dry ageing' is likely to carry more consumer appeal than 'wet ageing', but in truth the marketing term for wet ageing will be 'extra matured' and will make no mention of the term 'wet'.

5.4.5.3. Maturation Period

Beef improves as it ages, provided that enzymic breakdown can continue. This improvement is rapid over the first few days and then slows.

It is generally accepted that about 70% of the improvement happens in the first few days, whilst the meat continues to improve up to at least 21 days, although some argue that up to 28 days is beneficial.

[42] O'Halloran et al, 1997
[43] Troy and Kerry, 2010

5.4.6. Muscle Selection for Different Products

Muscle flavour differences have been reported in many studies[44]. Generally the differences in flavour intensity are small. Results from the study of Jeremiah et al. (2003) showed that sensory panellists scored "beef intensity" over a range of only 10% after tasting 33 different beef muscles.

Slightly higher differences were shown in flavour intensity between major beef muscles where the hindquarter muscles especially the biceps femoris had the strongest flavour intensity (Carmack et al., 1995). Both Jeremiah et al., 2003, Carmack et al., 1995 concluded that juiciness as measured by panellists was higher in the forequarter and loin muscles than the hindquarter muscles.

Meat tenderness differs very substantially between different muscles. This true for all species considered in this report, but which is particularly apparent in cattle.

5.4.7. Packaging Types Used

The type of packaging used can impact on the eating quality of meat. It does this via a number of different mechanisms. Vacuum packed meat allows continued enzymic breakdown of the bonds between muscle fibres. Modified atmosphere packing increases the oxygen and carbon dioxide content of the package and causes the meat to go bright red. However, a higher content of oxygen in the packaging is thought (at least in some cases) to cause rebinding of muscle fibres, toughening the meat again [45] [46]

5.5. Other Less Common Factors with Potential to Influence Meat Eating Quality

5.5.1. Hot Boning

Hot-boning is a process which was developed in response to commercial demands to lower energy usage and chiller space requirements[47]. It can be described as the removal of muscle or muscle systems from the carcass prior to chilling (normally within 90 minutes post-slaughter). Benefits include reduced carcass weight loss, reduced drip loss, lower energy use, reduced chill requirements, reduced labour costs and increased functionality of proteins for use in further processed products[48].

Despite such benefits, hot boning has not been adopted by the meat industry on a widespread basis. Certainly, retrofitting of facilities, training of staff, hygiene considerations and a more careful synchronisation of the slaughter, boning and processing operations would require modifications and investments. However, one of the primary reasons for its poor uptake is the potential of hot boned muscles to shorten in the absence of skeletal restraint and produce very tough beef.

5.5.2. Muscle Restraint

Recently, research has focused on restraining techniques of hot boned individual muscles to prevent shortening. This is not unlike targeting muscles and ensuring that they are prevented from shortening. The results generally show an increase in sarcomere lengths, decrease in shear force and an increase in tenderness[49]. Prevention of hot boned

[44] Calkins and Hodgen, 2007, Jeremiah et al., 2003

[45] Shengjie Li, Xiuxia Guo, Yuqing Shen, Jinfeng Pan, Xiuping Dong: Effects of oxygen concentrations in modified atmosphere packaging on pork quality and protein oxidation, Meat Science, Volume 189, 2022

[46] Yuqing Shen, Xiuxia Guo, Xiuping Li, Wenhui Wang, Shouyin Wang, Jinfeng Pan, Xiuping Dong, Shengjie Li, Effect of cooking temperatures on meat quality, protein carbonylation and protein cross-linking of beef packed in high oxygen atmosphere, LWT, Volume 154, 2022

[47] West, 1983

[48] Pisula & Tyburcy, 1996

[49] Sørheim & Hildrum, 2002

muscle shortening can utilise mechanical devices such as clamps to fix or stretch the muscle. Although cumbersome and time-consuming, the results are effective[50]. A more practical approach however seems to be wrapping or tightly binding muscles in film[51], or using an elastic film[52].

6. A Critical Evaluation of all Relevant Models of Assessing and Incentivising Eating Quality

6.1. Introduction

6.1.1. Beef Quality in Scotland

Currently in Scotland there is very limited measurement of eating quality of beef. The main quality distinguishers are breed (traditional) and maturation period, and whilst these do have some effect on eating quality, there is no real focus on ensuring that farm production more uniformly delivers a superior eating quality product. The delivery of this would require whole sectoral effort and the clear definition of production parameters to improve quality, an integrity system to ensure adherence, and a method of reward to encourage adherence.

Initially the focus would need to be on removing the outliers – those animals which have particularly low quality, before moving on to active improvement of the whole herd through the use of multiple quality predictors.

6.1.2. Beef Production Across the World

Throughout the world, beef production systems vary substantially. Throughout Europe, and Japan, herd sizes tend to be smaller, with more traditional production systems. In the USA and Australia, much beef production comes from large feedlots.

In the USA supply into those feedlots mainly comes from 'cow-calf' (suckler) systems of varying sizes, with some states in the USA having suckler herd average sizes around 18, although the average for the whole country is 40. The majority of the offspring from the herds are finished in feedlots. According the USDA[53] *"Feedlots with less than 1,000-head capacity make up most of U.S. feedlot operations, but they market a relatively small share of the fed cattle. Conversely, although feedlots with 1,000-head-or-greater capacity are less than 5 percent of total feedlots, they market 80–85 percent of fed cattle. Feedlots with a capacity of 32,000 head or more market around 40 percent of fed cattle"*.

The proportion of cattle finished in feedlots in the USA is high, and this means that there is a greater degree of conformity in finishing systems, carcass sizes, and even breeds than in Scotland. This alone means that the standardisation of carcasses is easier due to the lower number of farmers relative to the number of animals supplied.

The situation in Australia is slightly different. Calf production tends to take place in larger herds, and finishing of cattle in feedlots represents around 36% of cattle finished[54], with many cattle finishing on the farms on which they were born. It is more difficult to get uniformity of finish in Australia than in the USA, but still easier than in Scotland. Breed variation tends to be lower in Australia than in Scotland, but is still high due to multiple regions with different climatic conditions. Both USA and Australian beef production is predominantly (circa 75% USA and 93% in Australia) from beef suckler herds.

[50] Sørheim & Hildrum, 2002
[51] Devine et al., 1999
[52] Meixner & Karnitzschky, 2001; Troy, 2006
[53] USDA ERS - Sector at a Glance
[54] mla-state-of-industry-report-2020.pdf

Beef production in Japan is different, with a much narrower breed focus, mainly Wagyu, Wagyu/dairy cross and pure dairy breed. Much of Japan's beef is imported (over $3 billion annually), so domestic production tends to focus on the production of higher eating quality meat from the Wagyu breed.

Much of the production in USA, Australia and Japan is now focused on the production of higher eating quality animals. This has been encouraged by payment systems which reward quality indicators. These systems are discussed below.

6.1.3. Eating Quality Grading Systems

The primary goal of the Scottish red meat sector should be to put more focus on the eating experience of the consumer, delivering greater satisfaction. Typically, 15-20% of carcass weight is sold as prime steak. This governs 100% of consumer perception of red meat, especially beef. It is crucial that producers deliver a product to market that not only meets consumer expectations, but does it consistently. This involves establishing a robust method of measuring and managing quality within the current infrastructure of the supply chain and ensuring the Scottish brand is enhanced.

An improvement in meat eating quality is expected to have a substantial impact on the national and international competitiveness of the Scottish beef sector. A crucial aspect of driving this improvement is the ability to quantify meat eating quality, and its nutritional content. Furthermore, the importance of providing consumers with a consistent quality product has never been greater.

Meat quality can be described as the sum of all quality factors, including sensory, nutritive, hygienic, toxicological and technological properties[55]. Sensory properties include tenderness, colour, flavour, odour and juiciness, with tenderness being the most desirable meat eating quality trait. Nutritive factors include fat and protein content as well as vitamins, minerals and biological value. Sensory properties in particular are influenced by many factors, making beef quality highly variable, highlighting the need to develop methods of assessment soon after slaughter.

A range of eating quality grading systems can be found globally, with the majority applying to beef production rather than lamb or pork.

There are a range of well-known meat quality grading systems in operation internally, for which information is publicly available. These include USDA (USA), MSA (Australia), and JMGA (Japan), which all focus on delivering an easy to interpret system for consumers to select meat. There are an additional two meat quality assessment systems that are lesser known; the Canadian and South Korean models.

In addition to this, there are multiple quality management systems in place within commercial supply chains. However, information on these schemes is not easily accessible.

The following table shows the type of systems which are in place across the world to measure and manage eating quality.

Table 1: Meat Quality Systems around the world

System	Method	Description	Origin
VBG 2000 Beef Cam	Passive	Yield and Quality grading (USDA) incorporating a VIA camera system	USA
JMGA	Passive	Yield and Quality grading and incorporates the MIJ-30 camera system	Japan
MSA	Passive	Yield and Quality grading	Australia
Canada	Passive	Yield and Quality grading	Canada

[55] Hoffman, 1987

Korea	Passive	Yield and Quality grading	South Korea

6.2. USDA Grading (USA)

The United States Department of Agriculture (USDA) quality grade is determined by considering the degree of marbling and firmness, as observed in the cut surface of the M. longissimus dorsi in relation to the carcass maturity. Higher graded carcasses are characterised by higher marbling levels at lower maturity. USDA Yield grades are based on a regression equation with inputs the amount of external fat, the amount of kidney, pelvic and heart fat, the area of the quartered M. longissimus dorsi and the hot carcass weight. The external fat is evaluated as the thickness at a point over the ribeye but may be adjusted to reflect unusual amounts of fat at other points (Anon, 2001). The grading system in the USA is based on two elements, a quality grade and a yield grade.

The quality grade has seven categories: Prime, Choice, Select, Standard, Commercial, Utility, and Cutter. The categories Prime, Choice, Select and Standard are used for younger prime animals. The Commercial, Utility and Cutter categories are used for older cattle and some of the younger cattle that do not qualify for the better grades going into the processed meat sector. To take the quality measurement, the carcass is graded between the 12th and 13th rib using a camera (VBG 2000) which determines rib eye area, yield grade and marbling. This is done on a bloomed surface and conducted by a USDA operative. The level of intramuscular fat (marbling) in rib eye muscle is categorised as: Slightly Abundant, Moderate, Modest, Small, Slight, Traces, and Practically Devoid.

The following diagram shows the differences between separate grades of meat assessed against the USDA standard.

The yield grade has five categories numbered from 1 to 5, with yield grade 5 being the most desirable as it is the highest yielding for saleable meat.[56], [57]

Payment is based on a mixture of yield grade and quality grade.

[56] Boggs, D.L. and Merkel, R.A. Live Animal, Carcass Evaluation and Selection Manual. Dubuque, IA: Kendall/Hunt Publishing Com pany, 1990.

[57] United States Department of Agriculture: Standards for Grades of Slaughter Cattle and Standards for Grades of Carcass Beef. A gricultural Marketing Services, USDA. Washington, D.C., Government Printing Office, 1996.

A — 9 to 30 months
B — 30 to 42 months
C — 42 to 72 months
D — 72 to 96 months
E — more than 96 month

Degrees of Marbling	Maturity[2]				
	A[3]	B	C	D	E
Slightly Abundant	PRIME				
Moderate			COMMERCIAL	COMMERCIAL	
Modest	CHOICE				
Small					
Slight	SELECT		UTILITY	UTILITY	
Traces					
Practically Devoid	STANDARD			CUTTER	

[1]Assumes the firmness of lean is comparably developed with the degree of marbling and that the carcass is not a "dark cutter."
[2]Maturity increases from left to right (A through E).
[3]The A maturity portion of the figure is the only portion applicable to bullock carcasses.

FIGURE 2. USDA Beef Grading Chart: Relationship Between Marbling, Maturity and Carcass Quality Grade[1]

6.2.1. Relationship of USDA Grading to Eating Quality

Smith et al (2007) state that among Prime through Standard carcasses, grade predicted flavour, tenderness and overall palatability of loin steaks with 30% to 38% accuracy, but could explain no more than 8% of the variation in panel ratings/shear force values of round steaks.[58]

These findings are representative of other findings across the world, where the relationship between prediction systems and tenderness of meat is relatively loose.

6.3. JMGA System (Japan)

In Japan, the Japan Meat Grading Association (JMGA) deliver the beef grading standard, outputting a Yield Score and a Meat Quality Score (in a similar manner to the USDA grading system). To maintain the high standards expected, each carcass is individually assessed after slaughter by an association grader.

Meat quality grade parameters are assessed after quartering between the 5th and 6th ribs in JMGA grading.

[58] Smith, G.C. & Savell, J.W. & Cross, H. Russell & Carpenter, Z. & MURPHEY, C.E. & DAVIS, G.W. & ABRAHAM, H.C. & JR, F.C. & BERRY, B.W.. (2007). Relationship of USDA Quality grades to palatability of cooked beef. Journal of Food Quality. 10. 269 - 286. Beef Grading (beefresearch.org)

- Marbling is assessed against twelve beef marbling score (BMS) standards increasing in amount from 1 to 12. The BMS scores are in turn related to five beef marbling grades, Excellent (BMS 8–12), good (BMS 5–7), average (BMS 3–4), below average (BMS 2) and poor (BMS 1).
- There are five meat colour and brightness grades; very good, good, average, below average and inferior. Meat colour is assessed against colour standards (BCS) whereas brightness is judged by visual appraisal.
- Five firmness classifications are also utilised; very good, good, average, below average and inferior, and five texture categories described as: very fine, fine, average, below average and coarse. A final firmness and texture grade is produced from a combination of the two standards.
- In addition, seven Beef Fat Standards (BFS) are used to describe fat colour and a fat texture, lustre, and a quality grade is assigned from a combination of the BFS number and visual appraisal of fat lustre and quality. The fat colour, lustre and quality grades are described as excellent (BFS 1–4 and excellent lustre and quality), good (BFS1–5 and good lustre and quality), average (BFS 1–6 and good lustre and quality), below average (BFS 1–7 and below average lustre and quality) and inferior.

The Overall Meat Quality score (1-5) is based on these 4 assessments and is graded down to the lowest grade amongst these 4 items.

In 2017, Meat Image Japan launched the MIJ-Camera for taking clear and stable digital images of rib eye surface, making the visual assessment semi-automated and objective. Rib-eye area calculations are also highly accurate, as the technology uses automatic edge detection and can compensate for variations in cut angles and carcass rotations. The MIJ-30 is more accurate than manual subjective scoring system.

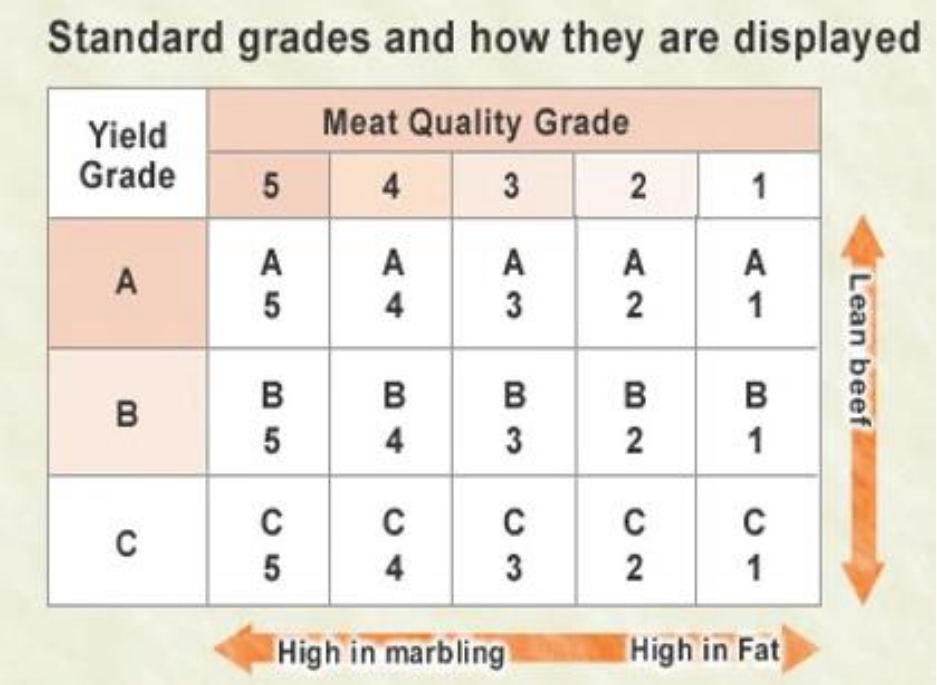
The Yield Score incorporates a series of measurements including:

1. Rib eye area (5^{th} and 6^{th} rib)
2. Rib thickness
3. Carcass weight
4. Subcutaneous fat thickness

Yield grade judges the final meat yield using defined calculations. There are three possible yield grades (indicating saleable meat yield on the carcass):

1. A – 72% and above
2. B – 69-72%
3. C – Under 69%

The final carcass grade is a combination of Yield and Quality Grade, with A5 being the best grade and C1 the worst.



There appears to be very limited evidence in the literature relating JGMA grade to the actual eating quality of the meat, but the parameters are very similar to those in the USDA system and can thus be treated in a similar way. Wagyu beef is highly marbled and therefore will benefit under the JGMA grading system.

6.4. MSA System (Australia)

The Meat Standards Australia (MSA) system is designed to improve and predict meat eating quality based on almost 1.2 million consumer taste tests by more than 171,000 consumers from 11 countries. The system has evolved to include a range of factors that influence meat eating quality such as marbling, fat, meat colour, ossification etc. (full list below). Furthermore, the MSA system incorporates another dimension of meat quality assessment; grading cuts according to a cooked portion, which further drives consistency for the consumer in terms of eating experience. This ultimately means that the same muscle could have a different grade depending on the method of cooking.

The MSA program has substantially impacted the Australian beef industry, driven by the accurate prediction of eating quality to deliver a product that consistently meets consumer expectations. The ability to deliver a consistent quality product of known eating quality ensures that value for money is always achieved, and research demonstrates that the consumer is willing to pay more for guaranteed quality. Furthermore, this system dramatically reduces the need for consumers to have any background knowledge of beef cuts and cooking relationships.

The eating quality prediction model accounts for the variation in genetics, production systems, cut and cooking method delivering an all-encompassing meat quality classification system. It includes a multitude of measurements:

1. Carcass weight
2. Sex
3. Genetics
    a. Mainly to account for the negative effect of Bos Indicus on eating quality (measurement of hump height)
4. Hanging method
    a. Achilles
    b. Tenderstretch
5. Growth promoters
    a. Accounts for the use of growth promoters which have a negative effect on eating quality
6. Ossification
    a. Prediction of biological age; younger animals have better eating quality

7. Marbling
    a. The level of intramuscular fat, which has a positive effect on eating quality. This is measured at the 12th rib
8. Rib fat
    a. Minimum rib fat of 3mm
9. pH and temperature
    a. Indicates nutritional management pre-slaughter
10. Eye muscle area
11. Fat colour
    a. Assessed on a scale of 1 to 7
12. Meat colour
    a. Assessed on a scale of 1 to 7
13. Milk-fed veal
14. Cut ageing
    a. Minimum of 5 days hanging
15. Cooking method
16. Individual cut

The system also uses some other indicators which are not applicable in Scotland, including Bos Indicus %, use of hormone growth projector implants, and hump height.

Within the grading system itself, an overall grade is given to the carcass which influences the total payment to the producer. There are four quality grades within the MSA system: Fail, MSA 3 Star, MSA 4 Star, and MSA 5 Star. Furthermore, the suggested cooking method for each cut, aimed at optimising consumer eating experience, are Grilling, Roasting, Stir fry, Slow cook, Shabu-Shabu (thin slice), and Corning. Fail meat is still sold but is not accredited.

The majority of carcasses are graded by an MSA-accredited grader; however, more work is being carried out to establish more objective measurement techniques such as the MIJ-30 camera system. By combining the MSA system with some of the technology available, an extremely robust system could be developed.

Table 1 *Summary of grading systems currently in use to predict beef-quality/eating quality (Farmer* et al., *2010a; Polkinghorne and Thompson, 2010; Bonny* et al., *2017)*

Grading scheme	Country	Grading unit	Number of grades*	Basis of grading
USDA	USA	Carcase	8 Quality grades	Sex; carcase weight; marbling; ossification; meat colour, texture; eye muscle area; ribfat; kidney and perirenal fat
Canada	Canada	Carcase	5 Quality grades (+ subgrades)	Sex; conformation; carcase weight; marbling; meat colour, texture; fat colour, thickness
EUROP	Europe	Carcase	5 Classification grades for conformation and fat (+ subgrades)	Sex; conformation; carcase weight; fat cover
JMGA	Japan	Carcase	5 Quality grades	Sex; carcase weight; marbling; meat colour, brightness, texture; fat colour, lustre, texture, firmness, thickness; eye muscle area, rib thickness
Korea	South Korea	Carcase	5 Quality grades	Sex; carcase weight; marbling; meat colour; fat colour, firmness, texture, thickness; lean maturity; eye muscle area, rib thickness
South Africa	South Africa	Carcase	3 Classification grades (+ subgrades)	Sex; carcase weight; dentition; ribfat; damage
Quality Mark	New Zealand	Carcase	Pass/fail quality grades	Country of origin; age; handling; absence of growth promoters; licensed plant; ultimate pH
MLC Blueprints (+ updates)	United Kingdom	Carcase	Pass/fail quality grades	Age/sex; growth rate; diet; EUROP grade/fat class; transport and lairage handling; slaughter techniques, defects; hanging; electrical stimulation, chilling and pH/T decline; maturation
Red Tractor and Quality Standard Marks	United Kingdom	Carcase	Pass/fail quality grades	Age/sex; EUROP grade/fat class; maturation
AUS-MEAT	Australia	Carcase	Classification grades	Diet; carcase weight; dentition; fat; sex; shape; marbling; meat colour; fat colour
MSA	Australia	Cut	3 Quality grades	Bos indicus %; hormonal growth promotor implants; carcase weight; sex; hump height; electrical stimulation; hang; marbling; ossification; meat colour; pHu; ageing time; cooking method

USDA = United States Department of Agriculture; JMGA = Japanese Meat Grading Association; MLC = Meat and Livestock Commission (now Agriculture and Horticulture Development Board); MSA = Meat Standards Australia; pHu = ultimate pH.
*Classification grades are descriptive terms for the carcase to aid trading while quality grades aim to place a value on the carcase on the basis of its perceived quality. Grades may also indicate yield (Polkinghorne and Thompson, 2010) but this aspect is not discussed in this paper.

6.4.1. Relationship of the MSA System to Eating Quality

Bonny et al (2018)[59] concluded that an MSA-like grading scheme could be used to predict beef eating quality and hence underpin commercial brands or labels in a number of European countries, and possibly the whole of Europe. They used MSA testing protocols to test a total of 22 different muscles, cooked by four different cooking methods and to three different degrees of doneness.

The team presented samples to over 19,000 consumers from Northern Ireland, Poland, Ireland, France and Australia. Consumers scored the sensory characteristics (tenderness, flavour liking, juiciness and overall liking) and then allocated samples to one of four quality grades: unsatisfactory, good-every-day, better-than-every-day and premium. They observed that 26% of the beef was unsatisfactory. They found that 68% of samples were allocated to the correct quality grades using the MSA grading scheme. They additionally found that only 7% of the beef unsatisfactory to

59 Review: The variability of the eating quality of beef can be reduced by predicting consumer satisfaction.
Bonny SPF, Hocquette JF, Pethick DW, Legrand I, Wierzbicki J, Allen P, Farmer LJ, Polkinghorne RJ, Gardner GE: Animal. 2018 Nov;12(11):2434-2442.

consumers was misclassified as acceptable. Other evidence shows that there is a good, but not exact relationship between MSA system measurements and actual eating quality.

6.4.2. Meat Eating Quality Probe

A probe which predicts intra-muscular fat has recently been approved for used in the MSA lamb system. The probe is used in abattoirs and is capable of operating at line speed. The hand-held probe has three imaging needles which are inserted into the loin muscle at the 12-13th rib of hot carcasses where it undertakes a spectral analysis to predict IMF. The data from the system is able to be used to inform branding and alignment to customer specifications. It also permits feedback to farmers, enabling effective decision making and helping to add additional value to the lamb industry. The information from the probe is another component which can be used to indicate a proportion of the eating quality of the final product. The probe works on the basis of hyper-spectral analysis, detecting differences in lean and fat tissue.

6.5. Canadian System

The Canadian grading system utilises maturity and marbling in assigning quality grades. The system standards were amended in 1996 to align its marbling standards with the USDA system. There are several quality grades for young cattle which are: Prime, AAA, AA and A. Grade B applies to young animals which do not meet the criteria to reach A-grade. Additional grades apply for cows and bulls (including young bulls which typically go into further processed products), D and E respectively.

The following diagram outlines the system for grading young animals in Canada and compares it to USDA grading.

GRADE	MARBLING*	MATURITY**	MEAT COLOR	FAT COLOR	MUSCLING	MEAT TEXTURE*
CANADA						
Prime	Slightly abundant	Youthful	Bright red only	No yellow fat permitted	Good muscling or better	Firm only
AAA	Small	Youthful	Bright red only	No yellow fat permitted	Good muscling or better	Firm only
AA	Slight	Youthful	Bright red only	No yellow fat permitted	Good muscling or better	Firm only
A	Trace	Youthful	Bright red only	No yellow fat permitted	Good muscling or better	Firm only
UNITED STATES* **						
Prime	Slightly abundant	Maturity class A & B	Light red	Yellow fat permitted	No minimum requirement	Moderately firm
Choice	Small	Maturity class A & B	Dark-cutters permitted	Yellow fat permitted	No minimum requirement	Slightly soft
Select	Slight	Maturity class A	Dark-cutters permitted	Yellow fat permitted	No minimum requirement	Moderately soft
Standard	Practically devoid	Maturity class A & B	Dark-cutters permitted	Yellow fat permitted	No minimum requirement	Soft

* Minimum marbling and meat texture permitted for quality grade class. ** Maturity categories reflect domestic requirements. *** Standards as of March 2009.

The Canadian grades exclude carcasses with yellow fat and require good or better muscling and firm lean texture. Maturity is assessed as youthful or mature on the basis of skeletal development. Meat colour is assessed at the ribeye (M. longissimus dorsi) surface quartered between the 12th and 13th ribs. Fat colour including internal fat is also assessed together with meat texture and carcass confirmation. Canadian yield grades relate to the amount of muscle in the carcass, with three yield grades designated as Canada 1, Canada 2 and Canada 3. The Canadian grading system is based on very similar scientific evidence to the USDA and JMGA systems.

6.6. Korean System

The Korean beef carcass grading system incorporates quality and yield grades, with five quality grades and three yield grades, resulting in 15 possible categories. The quality grade is based on marbling score, lean colour, fat colour, firmness, and texture of the lean meat, and maturity of the exposed M. longissimus dorsi muscle at the 13th rib. The yield grade is based on carcass weight, subcutaneous fat thickness, eye muscle area, and ossification score.

Kim and Lee (2003) showed that whilst this grading system was designed to reflect consumer preferences, there was large degree of variation within the grades, causing much overlap in consumer eating experience. Further work is being done to produce a prediction model that reflects consumer satisfaction better, similar to the MSA model.

6.7. South Africa

A meat eating quality prediction system is also operated within South Africa. This system has three main classification grades with three subgrades. The system uses the sex of the animal, carcass weight, dentition, rib fat cover and carcass damage to classify carcasses. The system works as follows:

Age Grading:

1) A grade: No incisors (12-14 months of age)
2) AB grade: 2 incisors (14-24 months of age)
3) B grade: 3-6 incisors (24-26 months of age)
4) C grade: Over 6 incisors (36 months and older)

Fat Cover
Fat cover: Animals are rated from 0 (lean) to 6 (extremely fat).

Sex
The sex of the animal is considered in grades B and C

Carcass Conformation
Carcass conformation is rated from 1 to 5.

Carcass Damage
Carcass damage is rated from 1 to 3.

Carcass Colour
White fat is also used as an indicator of high quality meat – being associated in South Africa with more rapid growth

Application
The above grades are combined using a clearly defined set of rules to produce grade indicators. The grades awarded are not necessarily to be used linearly. As an example, to achieve grade A, animals will normally have been treated with hormones which are associated with an increased level of toughness of meat. Consequently grade AB or B animals may have better eating quality.

6.8. Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) has been used to predict Intramuscular Fat Content, which itself is used as a predictor of eating quality (Lee et al., 2015). Statistical analysis showed that there was a strong correlation (R^2=0.98) between MRI images and chemical measurements for percentage IMF. To the best of our knowledge, this system has not yet been used in a commercial setting due to the size, weight and expense of the equipment.

6.9. Commercial Systems

Multiple commercial systems are on sale, based on a range of quality cues. These systems exist for all three species in the study. The key parameters used to indicate/manage quality are as follows;

1) Breed
2) Genetics
3) Sex
4) Fat class
5) Maturation
6) Diet
7) Rearing method

Many of these schemes are implemented within the context of a tiering system, with higher tiers of product being associated with more stringent quality controls. These systems do work: quality is raised and variability is reduced, and there is considerable verbal (non-attributable) evidence from retailers that a strong focus on quality which can be detected by consumers will substantially raise sales, even if the product is more expensive. The evidence is clear that consumers will pay for quality if it can be guaranteed.

All of the major multiple retailers in the UK operate tiering systems on beef, most also do so on lamb, and some operate a tiering system on pork.

All of these systems are built on a range of quality indicators, although some (such as rearing method) are tenuous at best.

6.10. Commentary on Eating Quality Systems

As already demonstrated, eating quality is impacted by a very large range of factors. Systems which are currently in use are broadly composed of very similar indicators or measures.

Some systems are focused on the prediction/management of quality across a very restricted range of indicators:

1) Single (or small number) indicator systems are not particularly accurate, but they are relatively easy to manage.
2) The more accurate systems take account of larger numbers of factors and combine them to produce a system which better reflects the actual quality of the meat.
3) All available evidence shows that the development of accurate quality management and quality prediction systems must control as many influencing factors as possible, as well as implementing as many quality improvement practices as possible.

The most sensible approach to the development of an accurate eating quality guarantee would be;

1) To understand the impact of each individual component impacting eating quality.
2) To understand the combined impact of different combinations of factors impacting eating quality (which may be more than or less than the sum of the individual parts).
3) To understand points one and two for beef, pork and lamb.
4) To build a system from the most impactful components.
5) To implement a technical integrity programme which audits and assures the implementation of the programme.

However, the scientific literature is unclear on the impact of many of the above components, for two main reasons;

1) In many cases work has been carried out to study the effect of several components at once, and the confounding effects of these multiple factors make it difficult to determine the exact impact.
2) In many cases the work has not been carried out to isolate and indicate the effect of the specific component.
3) The combination of a multiple impacting factors is not necessarily the sum of the impact of the individual factors.

Regardless of the unsatisfactory nature of the science around the interaction of the different influencing components, eating quality management systems are still designed and operated across world and have been demonstrated to have a positive effect on quality. There are two aspects to quality systems – the factors used to manage quality and the factors which are used to indicate that quality to the consumer.

Virtually all quality indication systems do the following:

1) **Reflect the level of fat in the carcass**, with higher levels of fat being used to provide higher quality meat.
2) **Offer a focused range of meat cuts** – with specific meat cuts being focused on specific uses (e.g. only high quality steak cuts offered as steaks, only high quality roasting cuts such as heart of rump or three bone rib used as roasting cuts).
3) **Use longer maturation periods for the meat** (although this is not usual with pork). The consumer has gradually become educated that longer maturation periods are associated with better tenderness, and in some cases, flavour development.

Many quality indication systems utilise the following indicators:

1) **Breed differentiation:** Breed differentiation is commonly used in beef and occasionally used in pork. Breed differentiation is less regularly used in lamb.
2) **Packaging differentiation:** Occasionally skin-packing is used as a quality indicator, but it is more often used to control quality (as is vacuum packing).
3) **Star or grade indicators** used to indicate the eating quality of the meat.
4) **Tiering** as part of an own-brand range.

Many quality management (as opposed to indication) systems specify:

1) The use of **electrical stimulation** systems to control pH fall
2) The use of **ultimate pH** as an indicator of quality
3) The **type of packaging** used
4) The **maturation period** of the meat
5) The **type of cuts** which can be used in each product
6) The **fat class** of the carcass
7) The **breed** of animal which can be used

The Meat Standards Australia scheme has been developed over an extended period of time to reflect eating quality of meat by predicting it using knowledge of multiple influencing factors. The work carried out to develop the programme was extensive, and has been carried out in Australia and several European countries. One MSA development project tested 22 different muscles cooked by four different methods to three levels of doneness assessed by more than 19,000 consumers in Australian and Europe (Northern Ireland, Ireland, Poland and France). The system proved to be effective at reducing the level of unsatisfactory beef from 26% to 7%. The experiment considered impact on tenderness, flavour liking, juiciness and overall liking. The paper concluded that an MSA-like grading scheme could be used to predict beef eating quality in order to underpin commercial brands or labels in Europe. Additional work by

Bonny et al (2018)[60] concluded that an MSA-like quality-based grading system in Europe would reduce the variability in beef quality for consumers and provide a price signal to encourage the production of quality beef. However, for such a system to be implemented, it must be adapted to the European consumers and beef production systems. The linking of quality grades to consumer expectation is important.

Polkinghorne (2008) stated that an eating quality-focussed grading system needs to be demand-driven, starting with retailers, before significant commercial advantages can be made throughout the supply chain.

In contrast to the MSA system, Bonny et al. (2016c) demonstrated that the European conformation score (EUROP grid) had no relationship with eating quality, confirming findings from other work (Guzek et al., 2013).

[60]S.P.F.Bonny, J.F.Hocquette, D.W.Pethick, I.Legrand, J.Wierzbicki, P.Allen, L.J.Farmer, R.J.Polkinghorne, G.E.Gardner: Animal Volume 12, Issue 11, 2018, Pages 2434-2442

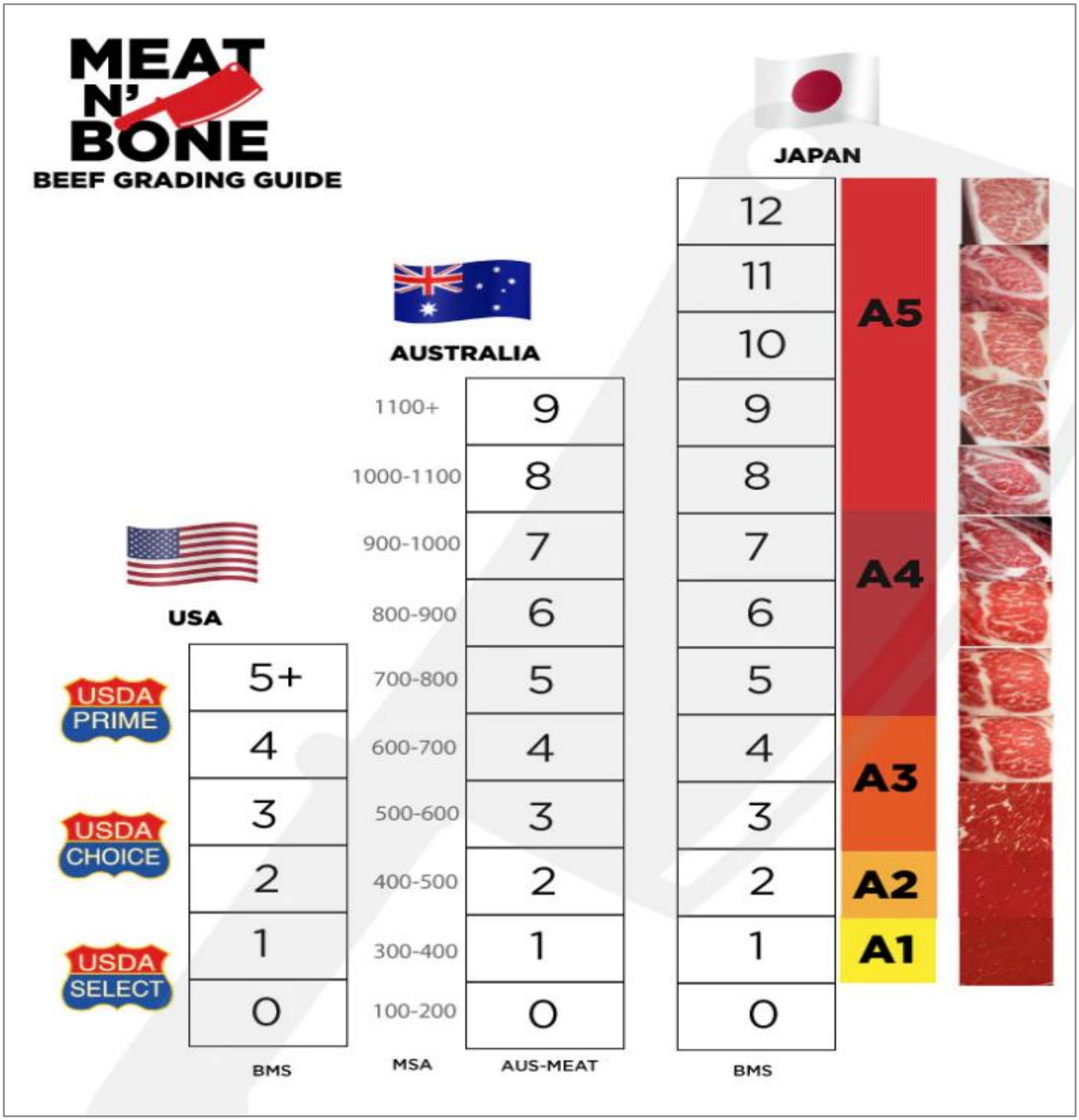
6.11. Summary of Indicators Included in Different Systems

The following table gives an indication of the components which are used as predictors of eating quality within each of the studied schemes. The MSA system is broadly recognised as the most comprehensive prediction system and it can be seen from the following table that it takes more factors into account than other systems. What can be seen is that in any of the systems, there are relatively few farm factors taken into account, and those considered are almost all within the control of the processor.

Table 2: An overview of Meat Standards Australia grading system in comparison to USDA, EUROP and JMGA, as described by Meat & Livestock Australia

	EUROP	MSA	USDA	JMGA	Canada	Korea
Carcass weight	X	X	X	X	X	X
Sex		X			X	X
Carcass conformation	X		X		X	
Carcass fat cover	X		X			
Genetics		X				
Hanging method		X				
Growth promoters		X				
Ossification		X	X			X
Marbling		X	X	X	X	X
Rib fat		X	X	X	X	X
pH and temperature		X				
Eye muscle area		X	X	X		X
Fat colour		X		X	X	X
Meat colour		X	X	X	X	X
Meat texture			X	X	X	X
Meat firmness			X	X		X
Milk-fed veal		X				
Cut ageing		X				
Cooking method		X				
Individual cut		X				

The Meat and Bone organisation produced a guide to beef grading under the USA, Japanese and Australian systems. The figure below outlines this comparison. The basic scales are similar, and the systems all account for level of marbling in the meat.



7. Technology for Measuring Eating Quality

The following information is taken from information published by Beef Central[61] and other commercial publications. It outlines a range of measurement technologies which can be used to measure eating quality:

7.1. Hyper-Spectral Imaging

Hyperspectral imaging has been demonstrated to have potential in the prediction of meat tenderness as measured by instron analysis. No commercial hyperspectral analysis system is currently in operation, partially because of the cost of full hyperspectral scanning equipment and its general lack of robustness in production environments (which is solvable).

7.2. Multi-Spectral Imaging Camera

The multi-spectral imaging camera is a simpler form of the hyperspectral camera. Instead of using a full hyperspectral scanning camera, a multi-spectral camera scans a specific set of wavelengths, meaning that the camera can be much simpler and less expensive. The multi-spectral camera is calibrated using hyperspectral imaging which picks out the wavelengths which are related to the eating quality of the meat.

7.3. Frontmatic Loin-Eye Camera

This is a hyperspectral camera that takes multiple images at several different light wavelengths. It is able to measure eye muscle area, as well as MSA marbling score, meat colour and fat colour to a relatively high standard. The system is still at the prototype stage, but is showing promise, and the developers believe that it will be able to meet AusMeat accreditation guidelines. A commercial version is under development.

7.4. Meat Industry Japan Camera

The meat industry in Japan has been developing a camera to grade Wagyu cattle, but the system has now been tested for the MSA system marbling assessment. The team have found that the results are consistent and that the system has potential to be developed. Further work is required to train the data, and to prove the algorithms for MSA traits.

7.5. VIAScan camera

In Australia, the VIAScan system is being used to grade carcasses in some factories for the retailer Woolworths and is being developed by Marel. The camera uses red/green/blue vision camera technology and is showing promise in accuracy of prediction. The company is carrying out additional repeatability trials.

7.6. MasterBeef Camera

The MasterBeef camera technology uses an app on hand-held smart-phone cameras. The app on the phone is used to generate a suite of data from the photo image, including Intra-Muscular Fat (IMF), marbling score, eye muscle area, marbling fineness and distribution, meat colour and fat colour and shows potential. Work is now focusing on developing calibration and validation on all traits, and scrutinising the repeatability between systems and set-ups.

7.7. E+V Camera

The E+V camera system is already widely used in the US beef processing industry to measure marbling scores. It has now been approved for the MSA system, measuring four MSA carcass traits – Meat Colour, Fat Colour, AusMeat marbling (0-5) and MSA Marbling (100-700).

Other MSA traits like rib-eye area, pH decline, fat depth and ossification are still assessed manually, but the intention is to include additional features as the system is developed.

[61] Objective measurement tools for eating quality making rapid progress - Beef Central

8. Summary Figures: Factors Influencing Eating Quality

8.1. Table of Magnitude: Factors Influencing Eating Quality

Table 3 summarises the information on eating quality which have been identified as part of this report. The table also summarises the mode of effect and estimates the magnitude of effect of the component. Pogorzelski et al. (2021)[62] (among others) provide good summary evidence of the impact of some of the factors we have highlighted in this report. As part of this review paper, attempts were made to isolate individual factors to give an overview of the magnitude of the effects of each factor and to understand which have the greatest impact.

Mode of effect	Size of impact	Potential verification method
Genetics		
The genetics of the animal affect quality through: * Muscle fibre type and distribution * Fat distribution * Intramuscular fat % in relation to subcutaneous fat % * Temperament of the animal (susceptibility to stress) * Enzyme content (e.g. Calpastatin) * Proportion of different cuts in the carcass	The magnitude of effect of genetics is difficult to isolate and quantify in many cases, primarily because there are so many factors which impact quality. The evidence suggests that the genetics has proportionally more influence on eating quality of the population for cattle and pigs when compared to lambs.	Use of DNA sampling can verify and potentially identify markers/genes associated with high eating quality. A previous QMS report (The Potential for Using Maternal DNA to Enable Transformative Genetic Progress and Full Chain Integrity, 2019) and a subsequent proof-of-concept have demonstrated that the effective use of DNA sampling can bring additional benefits to the supply chain (through identifying beneficial genetics within the supply chain) and can add value to the end product.

[62] Grzegorz Pogorzelskia, Paweł Pogorzelski, Andrzej Półtoraka;https://www.sciencedirect.com/science/article/abs/pii/S1871141321004030?casa_token=h-a9eS7QSdgAAAAA:lTBwQqlMh8oqBQMQhDt6BbNP-EVAZQ_G99kprl0X-o3UrQhpieQgIvFmX9aTM1fYQWzSZGVswg Jean-François Hocquette, Agnieszka Wierzbicka. Towards an integration of pre- and post-slaughter factors affecting the eating quality of beef: Livestock Science, Volume 255, January 2022.

Sex of the animal		
Bulls vs steers vs heifers have different muscle fibre types, muscle structure, muscle proportion, fat content and connective tissue. Each of these factors impacts overall eating quality.	The literature is divided on the impact of sex of cattle on eating quality (primarily tenderness). The general understanding is that around 15/16 months of age bulls start to become tougher than steers or heifers. This could be partially a result of the lower overall fat content, and the fact that bulls tend to be more susceptible to stress than steers or heifers. Again the literature is divided on the impact of age, but strong evidence exists that at around 7 months of age, some ram lamb start to display taint characteristics. The exact reason for expression is unclear and not all 7 month ram lambs will show taint, but there is a significantly increased chance of this happening. The literature is clear that for pigs, some boars start to display taint characteristics at around 110kg. This is not a problem for further processed products such as bacon or ham, but it is a problem for fresh pork and lighter animals (75kg carcass weight) should be processed for roasting meat and steaks. Again, the magnitude of this effect is difficult to determine.	Sex of the animal is easy to verify and is already recorded.
Management Methods		
Good handling of animals leads to: * low stress levels * rapid growth to finish (younger animals, more tender at finish) * good disease control, leading to rapid growth	Pre-slaughter handing of animals is recognised in the literature as being of extreme importance to the wellbeing of the animal and the subsequent meat quality of the slaughtered animal. Sheep are less susceptible to poor handling than cattle or pigs, but all suffer detrimental effects to a greater or lesser extent. There is good scientific evidence of an impact on eating quality of poor handling, but the actual extent of this is not quantified in most cases. Both long and short-term (acute) stressors are recognised, with the long-term impacts being on-farm and the	The day to day management of animals is very difficult to assess. However, the general management system of the farm can be deduced from some basic information which can be obtained during a farm assurance audit or which can be submitted by farmers. This includes: * Diet type and volume (potentially from feeder wagon) * Age of animals at slaughter * Type of accommodation * Bedding used * Training courses on animal welfare and management attended by farm staff

	acute impacts being caused at loading, transport, unloading and lairage.	* Quality of animal handling equipment on-farm * Quality of loading/unloading facilities
Animal Health		
Poor animal health restricts the growth rate of animals, leading to increased connective tissue and tougher meat.	The relationship between ill-health and eating quality is primarily driven by the speed of growth/age of animal at slaughter. The magnitude of the effect is even more difficult to determine than for speed of growth.	Age of the animal at slaughter is a relatively good proxy for health, as animals will not reach slaughter weight quickly if their health is poor. However, some animals will take longer to reach maturity as a result of management methods or diet, not because of ill-health.
The diet of the animal impacts the volatile fatty acid proportions which alters the flavour of the meat. Some consumers are able to detect grass fed versus concentrate fed beef, and particularly lamb. Pigs are generally fed on a very similar diet so this section does not apply to pork.	Measurement of the impact of diet on the eating quality of the animal has been repeatedly measured across multiple species and multiple diets. The general consensus is that there is an impact of diet on eating quality, but that this is also dependent on the animals to which the diet is fed, and the length of time for which the animals are fed on the diet. Predicting the relationship between diet and consumer liking is even more challenging, as consumers prefer different products. Broadly though, for ruminants, UK consumers prefer grass fed flavours, although to some extent even these flavours are lost when silage is fed unless some sort of protected linseed (or similar) is fed. Diet is essentially irrelevant for pigs as all pigs are fed on a similar diet in Scotland.	Diet can be difficult to verify, but some options exist. 1) Submission of a self-verified diet sheet with animals designated for slaughter 2) Use of an app to submit *purchase verification of concentrate feed *GPS verified details of grazing locations *feeder wagon data uploads *photos of fodder offered to stock It is also important to note that standardising this type of phenotypic data can be extremely difficult.

Age at Slaughter		
Younger = More tender Younger = Less connective tissue Younger = Less flavour	Cattle: The impact of age is primarily on toughness and has much more effect on bulls (3) than on steers (2) or heifers (2) 2 (Sheep): Age has relatively little effect on lamb, with the exception of ram lambs over the age of about 7 months, some of which tend to develop a taint. 2 (Pigs): Boar pigs tend to have a high incidence of boar taint over about 110 kg carcass weight, which is related to age	Age is relatively easy to verify through ScotEID for cattle. Lambs are usually managed seasonally, and a cut-off date of around September could be set for entire male lambs. Boar eating quality can broadly be monitored through the weight of the animals. A figure of 110kg could be used as a cut-off for higher/lower quality pork.
Fat Class at Slaughter		
Fat class is linked to Intramuscular fat (IMF) percentage. Rising IMF (to max of 7.3%) is linked to improved eating quality/increased consumer liking. IMF levels above 7.3% are associated with reduced eating quality/ consumer liking.	Fat class at slaughter is strongly correlated with the intra-muscular fat content of the meat. The literature is very clear that the IMF is related to overall consumer liking (R.K. Miller, in Meat Processing, 2002), through tenderness, flavour intensity, juiciness. However, the overall impact is relatively low (around 5%). We also speculate that the impact of intramuscular fat may be seen in the reduction of unacceptable outliers as well as in the improvement of overall eating quality. This is broadly true for all species, but it is recognised that because of the relatively low fat levels in pigs in Scotland, the positive impact of fat class on eating quality may be proportionally greater.	Fat class is easy to verify post slaughter and can be done through grading.

Transport		
Poor transport experience is associated with increased stress levels, increased use of glycogen by the animals, increased incidence of heat shortening and dark cutting meat. Poor transport can include: ** Poor loading/unloading leading to slips and falls.* ** Very long transport times.* ** Rough driving/twisty roads.* ** Unsuitable stocking rates (animals being thrown around the vehicle).* ** Mixing of unfamiliar animals leading to competition and fighting.* ** Bruising/physical damage.* ** Poor ventilation.* ** Absence of food or water over an extended period of time.*	Cattle: The impact of transport on eating quality is more severe on bulls than on steers or heifers, but all cattle are affected. Sheep: The eating quality of lamb tends not to be particularly badly affected by transport. Pigs: Pigs are relatively severely affected by transport and close attention to detail is required.	* Installation of G-meters in approved transport. * Close monitoring of each journey - submission of route maps by phone at start and finish of journey (hauliers and farmers).
Pre-Slaughter Handling		
Poor pre-slaughter handling is associated with increased stress levels, increased use of glycogen by the animals, increased incidence of heat shortening and dark cutting meat. Poor pre-slaughter handling can include: ** Long withdrawal periods from food and water.* ** Mixing of unfamiliar animals leading to competition and fighting.* ** Handling by unfamiliar people.* ** Bruising/physical damage.*	Note: Lairaging, Pre-slaughter handling, Transport, Lairaging and Slaughter Facilities influence each other and overlap.	*Creation of app to monitor selection times and loading times via submission of photo to app. * Camera monitored selection and penning of stock for transport to slaughter. * Loading video submitted to prove low stress

Lairaging Process		
Poor lairaging is associated with increased stress levels, increased use of glycogen by the animals, increased incidence of heat shortening and dark cutting meat. Poor lairaging can include: ** Long withdrawal periods from food and water.* ** Mixing of unfamiliar animals leading to competition and fighting.* ** Handling by unfamiliar people.* ** Difficult movement of animals due to poor design.* ** Breakdowns leading to overcrowding as additional animals are delivered to the site.*	Note: Lairaging, Pre-slaughter handling, Transport, Lairaging and Slaughter Facilities influence each other and overlap, so the total impact is not the same as the sum of the individual impacts. Good handling cannot improve the meat quality, but poor handling can substantially reduce it. In general sheep are not particularly susceptible to stress, and practical experience shows this to be the case. On the other hand, pigs, and boars in particular are highly susceptible to poor pre-slaughter handling. Most of the impact of pre-slaughter handling is seen through carcass damage and meat which is pale, soft and exudative, or dark firm and dry. Cattle are somewhere in between. All cattle can be impacted by pre-slaughter stress, although bulls are particularly susceptible. In Scottish factories, this is mainly seen through heat shortened meat caused by high carcass temperature as the meat pH falls below 6.	* Fully trained and monitored lairaging staff * Artificial intelligence to monitor animal handling and anxiety levels via camera * Camera monitored staff behaviour * Temperature monitoring of animals by imaging camera
Slaughter Facilities		
Inappropriate slaughter facilities can increase animal (and operator) stress during the process of moving animals to the stun box. ** Poor movement channels can lead to animal damage, animal stress and increased glycogen use.* ** Poor stun box arrangements can lead to difficulty in moving animals into the box, again increasing animal stress.*	Good slaughter facilities have no impact on meat quality. Poor facilities cause stress, damaging meat for susceptible animals. The impact of poor lairage and slaughter facilities and practice is amplified if an animal has experienced difficult loading or transport conditions, or any sort of dietary challenge prior to transport.	* Slaughter facilities can be inspected and graded. * The grade for the facilities could be applied to all meat coming out of the plant. * Grading would provide an incentive for each plant to optimise its overall system. * The overall system should be considered, including the quality of the facilities, the quality of the staff training and an assessment of staff performance over two days of observation.

Slaughter Method		
The slaughter method can have an impact on the final meat quality of the carcass. * Electrical stunning/slaughter, if inappropriately tuned can cause blood splash and accelerate glycogen usage. * Captive bolt stunning, if inappropriately managed can lead to a non-stunned but highly stressed animal.	Usually slaughter method has no effect, but when it causes problems, they can be relatively severe. Ineffective stun is highly stressful, and it is important that whatever stun and slaughter method is used, it is regularly tested and maintained.	* Slaughter method is known * Records of double stuns/stun failure can be inspected, but the accuracy of this is sometimes questionable.

The MSA system uses a range of scientific literature to underpin the judgements that it makes. The following information is taken from a 2008 paper[63] and shows a range of indicators which are used, and their overall effect on the index (which is not the same as the overall effect on eating quality).

Table 1: The effect of carcase attributes on the MSA Index

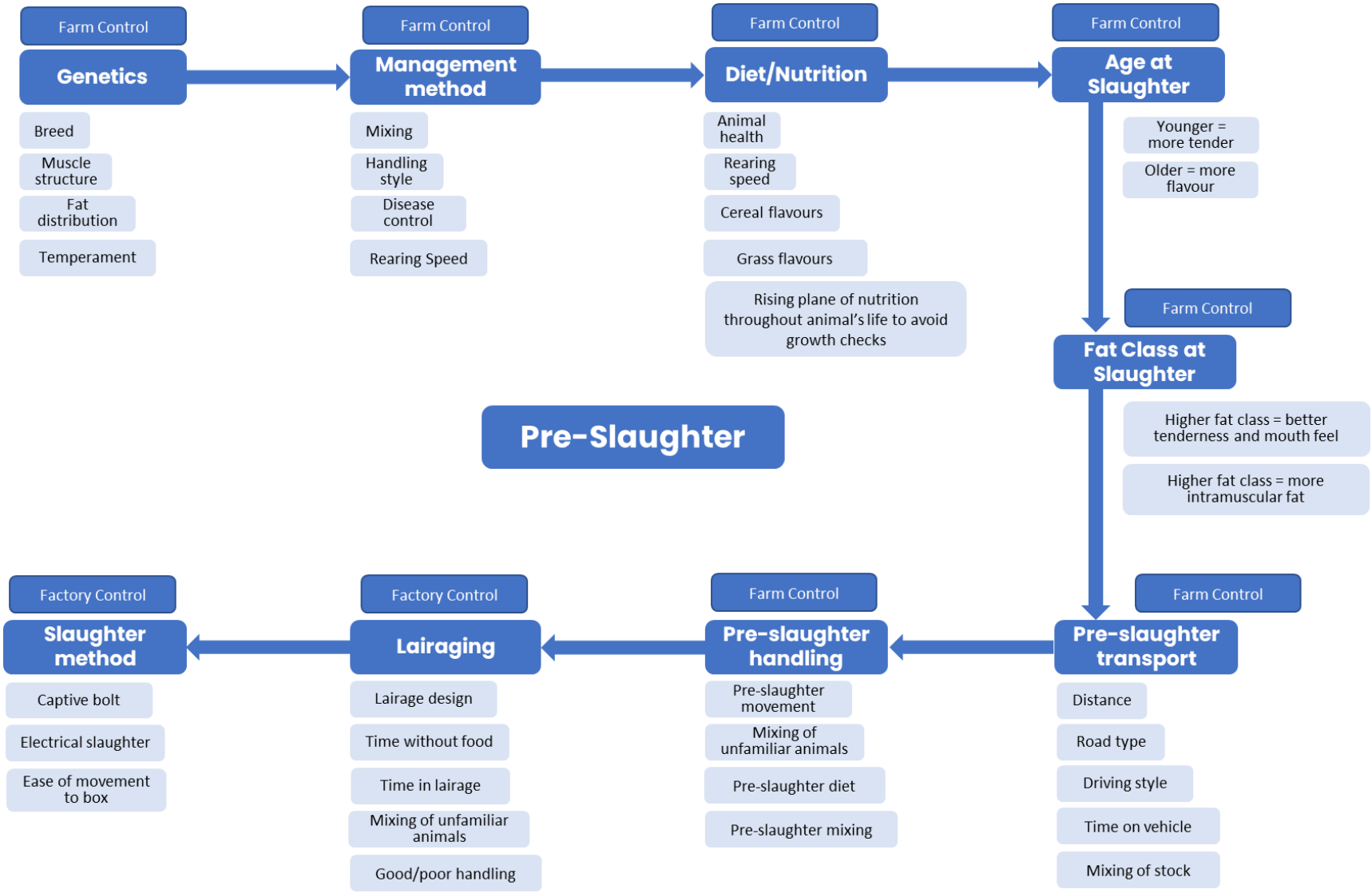
Carcase input	Size of effect on the MSA Index (units)	Clarification of effect	Relative importance of these traits in changing the MSA Index*
HGP status	5	The MSA Index of carcases with **no** HGP implant is around 5 Index units higher	**Very High**
Milk-fed vealer	4	The MSA Index of milk fed vealer carcases is around 4 index units higher	**Very High**
Saleyard	5	Carcases which were consigned directly to slaughter and NOT processed through a saleyard have an MSA Index around 5 index units higher	**Very High**
MSA marbling	0.15	As MSA marbling score increases by 10, the MSA Index increases by around 0.15 index units	**High**
Hump height (for cattle greater than 0% TBC)**	-0.7	As hump height increases by 10mm, the MSA Index decreases by around 0.7 units In carcases which have no TBC, hump height has no impact on MSA Index	**High**
Tropical Breed Content (TBC)**	0% = 0 12% = -1.6 18% = -3.2 25% = -3.9 38% = -4.7 50% = -5.2 75% = -5.5 100% = -6.3	As declared TBC content increases from 0 to 100%, the MSA Index decreases by up to 6.3 units	**High**
Ossification score	0.6	As ossification score decreases by 10, the MSA Index increases by 0.6 index units	**High**
Rib fat	0.1	As rib fat increases by 1 mm, the MSA Index increases by 0.1 index units	Medium
Hot standard carcase weight (HSCW)	0.01	As HSCW increases by 1kg, the MSA Index increases by <0.01 index units	Low
Sex	0.3	With low ossification values, females have a higher index value than steers by around 0.3 index units	Low

The values presented in Table 1 are the average effect calculated for 2.8 million carcases across all states of Australia.
* Relative importance indicates the size of effect changing that trait will have on the MSA Index within a herd, if all other traits remained the same.

63 Evolution of the Meat Standards Australia (MSA) beef grading system: R. Polkinghorne A F , J. M. Thompson B , R. Watson C , A. Gee D and M. Porter: Australian Journal of Experimental Agriculture 48(11) 1351-1359 16 October 2008

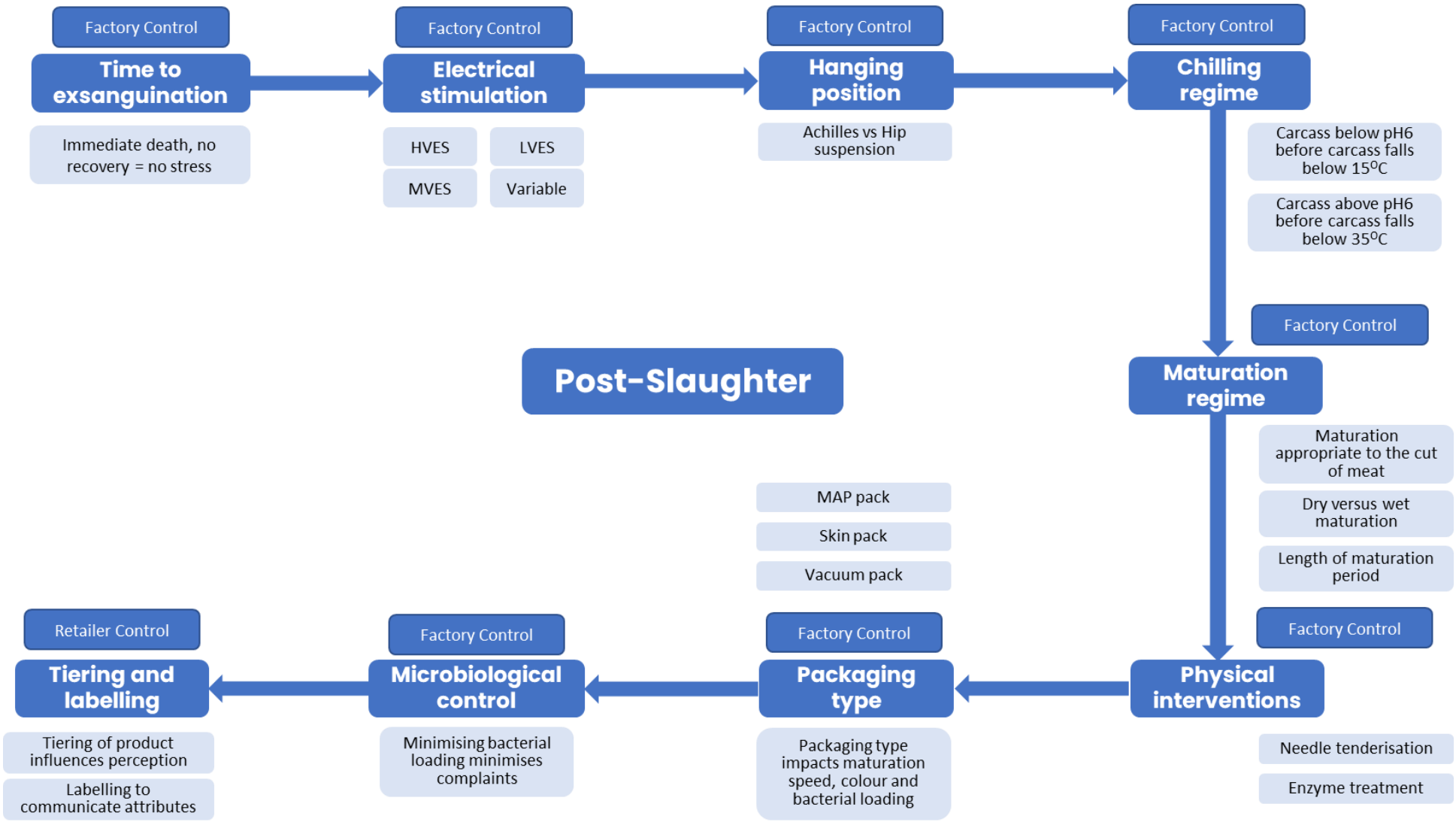
8.2. Figures Showing Pre-slaughter Factors which Impact Eating Quality

Figure 5 summarises the pre-slaughter components which affect the eating quality of red meat and the attributes of the animal which are affected by it.



8.3. Figures Showing Post-Slaughter Factors which Impact Eating Quality

Figure 6 summarises the post-slaughter components which affect the eating quality of red meat and the attributes of the animal which are affected by it.



9. Part 2: Critical Evaluation of the Effectiveness of the EUROP Grading System in Incentivising Carcass Quality

9.1. Evaluation of Current Systems in the UK and their Ability to Recognise Meat-eating Quality

9.1.1. Introduction

The EUROP carcass classification grid was introduced to Europe in the 1970's with the aim of ensuring that a uniform classifying system could be used across the continent for beef and lamb. This grid also meant that producers could be rewarded for supplying cattle and sheep with the carcass classification (and therefore yield of carcass cuts) that the market demanded. It reflects the proportion and yield of cuts which will result from a carcass of a particular weight, allowing pricing of the carcass to take place. The system was not designed to reflect eating quality and there is almost no relationship between the carcass grade and the eating quality of the meat.

The EUROP classification uses the grades E, U, R, O, P to describe the muscularity or conformation of a carcass, and a 1 to 5 assessment for fat cover, both of which serve as a basis for outlining specifications and pricing grids. Approximately 85% of the market requires conformation of E, U, R, & O and fat classification of 2, 3, & 4, in both beef and lamb within predetermined weight ranges; however, the majority of these specifications have no or limited measurable meat quality-based criteria. Furthermore, this grading is largely subjective (some objective scoring systems are in place), driving huge variability and inconsistencies within the supply chain. Research has shown that bias can occur between groups of carcasses, classifiers' judgment can vary over time, and differences can be observed between classifiers[64]. In the UK the focus is, and has been, on yield prediction; however, by only considering these visual attributes and ignoring the quality, such a system incentivises producers to deliver a product that may not at all meet the expectations and needs of the consumer.

The EUROP grading system has been in place since the 1970s and, as such, could present a number of difficulties in replacing it for a more modern system. The EUROP grid was initially introduced to assess beef carcasses; with a focus on external attributes and no direct consideration for meat quality. However, during this project we will evaluate the usefulness of the data collected within the EUROP grading system, along with other animal data (age, sex, breed, etc.) in predicting meat quality. Furthermore, we will investigate add-ons to the EUROP grading system that could deliver a more accurate prediction of meat quality.

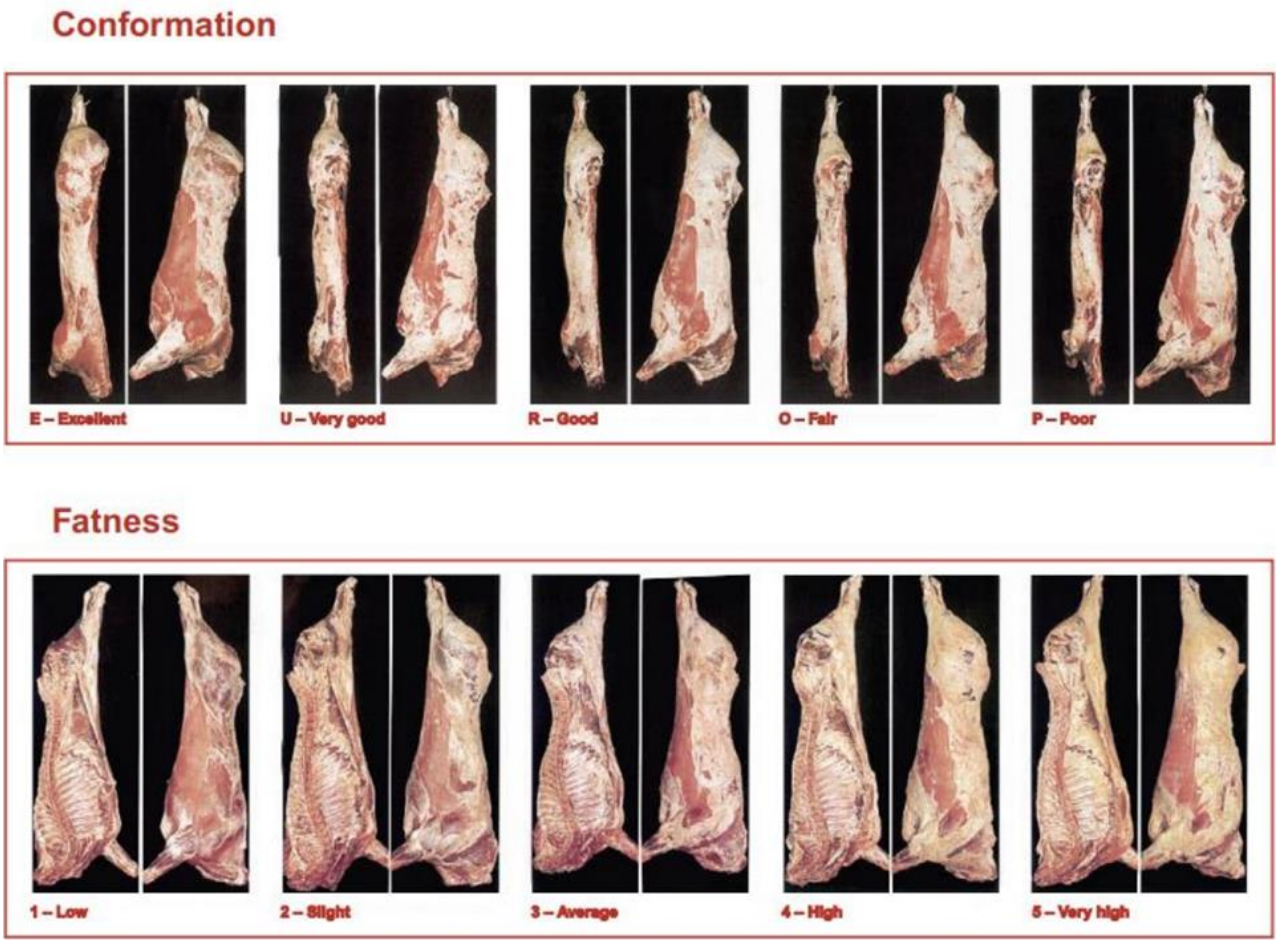
9.1.2. The Current Grading System

The EUROP grading system was largely developed to improve transparency and efficiency within the beef supply chain. It provides a common language between producers, processors, and wholesale / retailer that facilitates fair payment and benchmarking across the industry, promoting trade and market development.

When cattle or sheep carcasses are classified, they are described by both conformation and fat class. Conformation is a visual assessment of the overall shape of the carcass using the EUROP scale; conformation class E describes carcasses of outstanding shape, and conformation class P describes poorly muscled carcasses of inferior shape. Fat class is assessed from 1, being very lean, to 5, being very fat (Figure XX).

[64] Boggaard et al., 1996

Figure 7: Assessment of Conformation and Fat class under the EUROP Grading system (Source MLCSL)



At present the only mechanical assessment method approved for use in the UK is the VBS 2000 (e+v Technology) machine.

Within the UK, this grading system does not relate well to consumer sensory scores, being poor at discriminating eating quality when assessed against consumer taste panels[65].

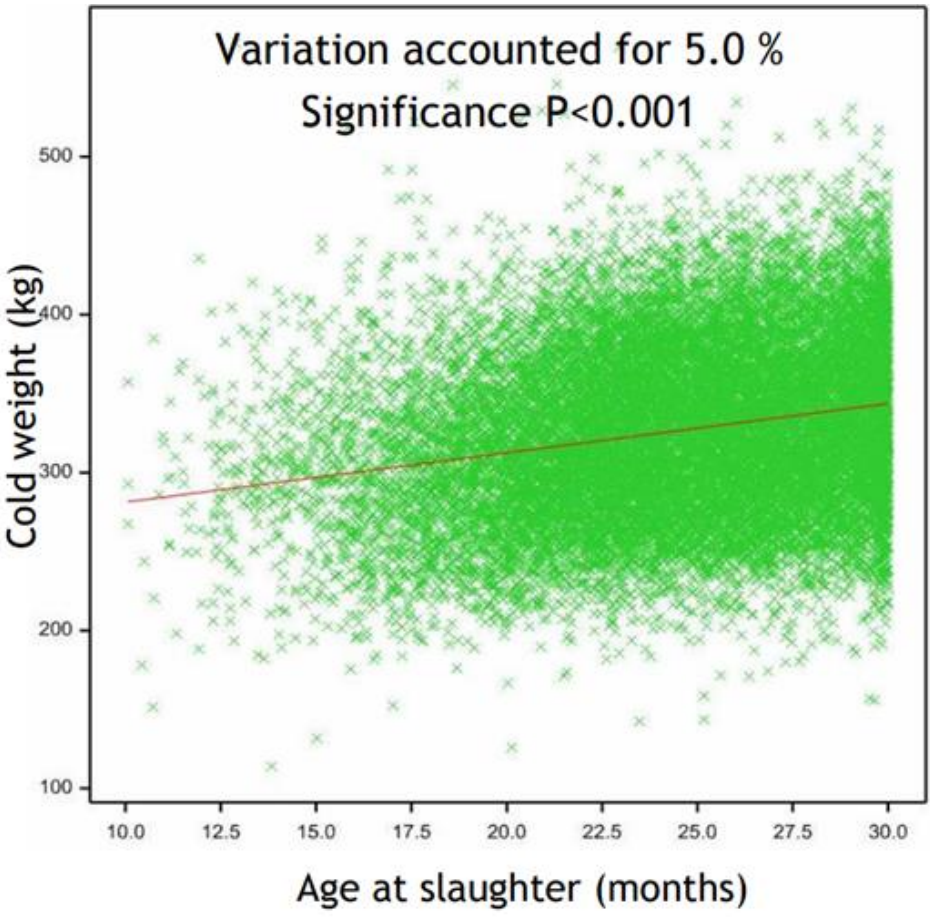
9.1.3. Variability and The Current Grading System

The current beef supply chain is highly fragmented, delivering a highly variable product due to a wide range in the age of slaughter, carcass weights, conformation grades, and fat classes. Figure 8 below illustrates the variability in age of slaughter against carcass weight of prime steers and highlights the extent of this problem. The full economic cost of such existing variable supply chains is large and economically unsustainable in the long-term. Processing facilities within the UK operate under very stringent conditions, and placing carcasses with this much variability within a robust chilling regime will undoubtedly result in a high degree of variability in pH-temperature decline and subsequent meat quality. The variability in the visual aspect of prime cuts and meat quality will result in low levels of consumer satisfaction.

[65] Polkinghorne and Thompson, 2010

To some degree (and as described earlier), much of the variability in carcass size and type is a product of Scotland's varied production systems and landscape, and has evolved over time. What is clear however, is that much of this variability can be addressed through appropriate market signals and the effective use of genetics and management practices, and, from a consumer perspective, it is important that this is delivered.

Figure 8: Age of slaughter against carcass weight of prime steers



Source: Bovine Information System Annual Report 2013

The aim of the EUROP grid was to classify carcasses and drive uniformity within the supply chain. However, many decades of use of the EUROP system has not had this effect and the intended consistency is not evident within the beef or lamb supply chains. Interestingly there is much more conformity in the pig supply chain which uses a very different system of grading based on weight and fat depth at the 11th rib. The conformity of the pig supply chain is also related to the much more cohesive and focused use of genetics.

9.1.4. Opportunity to Develop Meat Quality Indicators

It could be argued that the current EUROP classification system is completely outdated and requires immediate replacement, and there are many in the industry who would concur with this view. Their arguments are based on the fact that the system has been shown to encourage the production of an animal whose conformation is not suitable for today's marketplace (incentivising the production of a high proportion of roasting meat rather than steak meat) and does not include a quality prediction or measurement.

It is important to note that the EUROP system is well understood within the UK beef and lamb supply chain and it may be prudent to modify it instead of completely replacing it. This would lead to the smoother uptake of an eating quality standard, especially as rapid industry-wide adoption is highly desirable.

There are many opportunities to improve the current supply chain to deliver closer to consumer expectations. It is also fair to state that in its current format, this system will continue to hinder the development of the industry by failing to adequately deliver to consumer expectations. Without consumers, the industry will regress, and it is vitally important that future development is consumer focussed and their requirements are at the forefront of every business decision made within the Scottish meat supply chain.

9.1.5. Immediate Approaches (Low-hanging Fruit)

Improving the core product by delivering consistency in terms of age, weight, conformation, fat class and production method will dramatically improve the product delivered to the consumer.

9.1.5.1. Step 1

Tighten carcass weight specifications by creating 2 categories; Commodity and Prime. For example, having a carcass weight specification between 280-360kg for Prime cattle; a weight range within which primals are marketable, will greatly reduce the variability in terms of post-slaughter responses such as pH-temperature decline. This improved carcass response will produce a more consistently tender product with improved shelf-life.

9.1.5.2. Step 2

Reduce the age at slaughter for Prime cattle. This will not only improve production efficiency, but reducing the age at slaughter from its current position of more than 26.0 months to 15.0 months will reduce toughness associated with greater collagen cross-linkages, delivering a more consistent product to the consumer.

9.1.5.3. Step 3

Ensure that Prime cattle are only steers and heifers. Collagen matures more quickly in bulls, resulting in tougher meat. Stress levels associated with pre-slaughter handling are also much greater in bulls which can result in tougher meat; associated with greater collagen cross-linkages, poor ultimate pH; increasing the risk of dark cutting meat, and poor shelf-life.

These low hanging fruit may seem difficult to achieve on paper, but if incentivised, uptake would be immediate and a dramatic improvement in meat quality could be realised. For example, suckler beef production has the potential to be extremely efficient with animals reaching slaughter at 12 months of age. This can be achieved by focussing on critical developmental time points during early life that are crucial for the future growth potential of the beef animal. Critics may suggest that fat cover can't be achieved at such an age, but this is incorrect, any diet can be manipulated to achieve the desired fat level, irrespective of the age of the animal.

9.1.6. Meat Eating Quality Model Development

The ability to differentiate products in terms of meat quality enhances the marketing potential both domestically and globally. For example, the MSA system predicts the eating quality of individual muscles and recommends the optimal cooking method for maximum consumer satisfaction. Guaranteed eating quality is directly correlated with price and subsequent perception of value; value for money is rarely questioned when meat quality meets consumer expectations. Replacing or developing variable quality systems, such as EUROP classification, with accurate eating quality grades can underpin branded beef programs and provide a basis for improved demand.

Within the EUROP classification system currently, fat classification could be used as a vague predictor of eating quality; however, there is no ground truthing data to validate such hypotheses. Furthermore, within UK systems currently, there is additional, mandatory animal data collected that is currently not being utilised to assist yield or meat quality predictions. There is much opportunity to include such data in a meat quality prediction algorithm.

The development of a meat eating quality model would require some development of consumer education also. The USDA system has been criticised for causing 'substantial confusion' amongst consumers[66].

It is important to note, however, that any change to market requirements and payment systems will result in winners and losers. It seems likely that under a model which is focused on eating quality, animals which have been bred purely for carcass yield are likely to lose out. This means that, if the industry makes the decision to pursue eating quality as the primary focus, many breeders will need to adjust to ensure that they can benefit. There is clear scientific evidence that traditional breeds have an eating quality advantage over continental breeds. However, there is also evidence for variation in eating quality within all breeds, meaning that all breed societies could focus on improvement of eating quality to meet the demands of any new system.

9.1.7. Data Currently Being Collected

Every animal slaughtered in the UK today has a wealth of data associated with its identification that could be hugely beneficial in predicting meat eating quality. This includes sex, age, breed, dam, dam breed, movements, distance travelled, lairage time, electrical stimulation, hanging method, chilling regime, maturation method, maturation period etc. The models developed within the MSA system illustrate the importance of these factors in predicting meat eating quality.

Some of the potential influences these pre- and post-slaughter factors are outlined below:

9.1.7.1. Pre-slaughter Data Currently Being Collected

Sex

- In general, it is accepted in the literature that heifers tend to be more tender than steers which are more tender than bulls. Collagen matures more quickly in bulls resulting in tougher meat. Stress levels associated with pre-slaughter handling are also much greater in bulls which can result in tougher meat; associated with greater collagen cross-linkages, poor ultimate pH; increasing the risk of dark cutting meat, and poor shelf-life.

Age

- Reducing the age at slaughter from its current position of more than 26.0 months to 15.0 months will reduce toughness associated with greater collagen cross-linkages, delivering a more consistent product to the consumer.
- Weight for age could be an important factor in predicting meat quality. A higher weight (carcass weight) for age is likely to enhance meat quality due to reduced collagen cross linkages.

Breed

- Genetics directly affect muscle structure, type of muscle fibres, speed of growth of the animal, temperament of the animal and fat content of the meat (intramuscular fat content).

Movements

- Generally, the fewer the moves the less stress the animal has experienced. Stress can lead to more connective tissue and tougher meat.

Transport

- Minimising travel distance will improve meat quality.

[66] DeVuyst et al., 2014

Pre-slaughter Handling / Lairage time

- Stress depletes glycogen prior to slaughter and this can cause dark cutting meat or reduce the potential to age after slaughter.

9.1.7.2. Post-slaughter Data Currently Being Collected

Electrical stimulation

- Electrical stimulation was originally introduced to reduce the risk of cold shortening; however, within current chilling practices, electrical stimulation can increase the levels of heat shortening which will have a negative effect on meat quality.

Hanging method

- Pelvic suspension, as opposed to Achilles suspension, induces a stretching effect on key, high-value muscles, preventing the sarcomeres from shortening and in some cases actually stretching the distances between z lines.

Chilling regime

- Usually standardised to avoid cold shortening. Chilling systems will be set to ensure the carcass does not cool below 10°C before the muscles have gone into rigor. As a rule of thumb this has been taken as 'not below 10°C in 10 hours' from slaughter.

Maturation method

- Dry vs wet ageing. In general, dry ageing is limited due to added expense. However, dry ageing does intensify flavour which is associated with an improved eating experience.

Maturation period

- Eating quality increases with ageing (Savell, 2008); however, the rate of improvement declines with time, with suggestions that no additional benefit be incurred over 21 days (Campbell et al., 2001).

Additional data to collect

- Leading quality assessment systems globally incorporate more measurements that are directly linked to meat eating quality and are important considerations for the future meat eating quality assessment systems within the UK.

Marbling

- Marbling (intramuscular fat) is the dispersion of fat within the lean and is normally evaluated in the ribeye muscle. Increased marbling is associated with an increase in quality grade, in terms of both flavour and tenderness.

Rib fat depth

- Low rib fat depth is associated with poor quality; rib fat is associated with improved chilling and associated pH-temperature decline.

pH and temperature

- Important to remove any risk of heat and cold shortening which has a negative effect on meat quality.

Rib eye area

- Rib eye area deemed adequate, claimed to be an accurate representation of the whole carcass.

Fat colour

- A brighter and whiter fat is associated with increased quality.

Meat colour

- As maturity increases, lean becomes darker in colour.

Meat texture

- As maturity increases, lean becomes coarser in texture and is associated with reduced quality.

Meat firmness

- More meat firmness is associated with improved quality.

9.1.8. Validation

While the EUROP classification system is required for trade, a consumer-focused valuation system is also needed in order to increase value within the beef supply chain and improve the consistency and eating quality of Scottish beef. There are good examples of alternative grading systems which support this approach (e.g. MSA and USDA), and integrating versions of these systems in addition to EUROP, has huge potential in improving the footprint of Scotch beef in international markets.

A key element to enhancing the ability to quantify meat quality is the ground truthing and validation of models. It is essential that ample background scientific testing and validation is conducted to ensure robust evidence is accumulated and a high degree of industry confidence is established.

9.2. Delivering Practical Change

The delivery of practical change at farm level requires that multiple factors are taken into consideration. This includes a clear understanding of:

1) Farmer behaviour and motivation
2) Factors influencing farmer behaviour
3) The impact of specific incentives on specific behavioural factors
4) The impact of specific penalties on specific behavioural factors

9.2.1. Farmer Behaviour and Motivation

Farmer behaviour is both predictable and unpredictable. At a macro or group level, behaviour can be predicted, but at an individual level, it becomes more difficult. This means that there will need to be acceptance that some farmers will not comply with specifications around management of eating quality, but that as a group, management of eating quality is necessary.

It also means that there is a need to provide assurance around any eating quality claims which are made because, whilst the majority will comply with any requirements, some won't, undermining the quality claims which are made.

Farmers will not change without incentive to do so. There are two main high-level forms of incentive:

1) **Positive incentives**, where farmers receive some form of reward for compliance with requirements. These positive incentives include the following:
    a. Clear financial benefits, where payment for compliance is clearly defined and delivered;
    b. Other financial benefits, where the payment for compliance is not as obvious, but is real nonetheless, being delivered through access to higher paying markets, or through reduced cost of production;

c. Recognition, where farmers receive acknowledgement for positive behaviour, such as a recognition for improved environmental performance, or where peers provide positive feedback.

2) **Negative incentives**, where farmers receive some form of penalty for non-compliance with requirements:
   a. Clear financial disincentives, where farmers are not able to access markets with higher financial rewards because of non-compliance;
   b. Fines, where farmers have claimed compliance but have subsequently been shown to be non-compliant;
   c. Where farmers are dissuaded from compliance because of the work involved, a lack of knowledge, or the lack of a technical skill;
   d. Lack of recognition, or negative feedback from peers or other organisations.

There is also a third factor, which revolves around farmer understanding of the reasons for any specification requirements to which they have to conform. A lack of understanding has been shown to be a significant disincentive to compliance because within the correct level of understanding, some tasks are seen as meaningless and without value.

The design of incentives and the building in of disincentives to ensure compliance to specifications is critically important to any quality development and management system. In addition to this, a clear communication process must be put in place to ensure that the reason for each specification requirement is clear and that the methods of delivering against the requirements is also clearly understood.

Farmers in Scotland are mainly driven by market signals (usually price), legislative requirements, policy signals, level of knowledge and the technical ability of the farm team.

For many farmers, the main incentive is price, for better farmers the incentive is profit, and for a small but growing minority it is a balance of profit versus sustainability.

As previously discussed, the Scotch PGI has delivered over £100 million into the supply chain over the previous 10 years. This is a substantial advantage and farmers will be motivated to ensure that this premium remains or even increases in the future.

In addition to price, animal grading is a significant motivator within the red meat supply chain. It is perceived as being closely linked to financial return and many farmers try to produce higher grade animals to obtain a higher price per kg. This is not always cost-efficient but remains a significant driver of behaviour across all three species considered in this report.

CAP support has delivered behavioural change for beef and lamb, although the behavioural change cannot always be argued to have been beneficial. The annual total of CAP payments into Scotland is around £650 million, of which 51% supports active farming to provide a safety net for farmers and crofters by supplementing their main business income. Around 21% is provided through 'Greening' which is a policy aimed at agricultural practices beneficial for the climate and environment, paid on top of the basic payment scheme. The additional 28% is spent on Pillar 2 funding, which is provided to support agriculture in less favoured areas, other environmental programmes, forestry, and supply chain work. The post-Brexit environment means that farm support payments are going to change substantially and are highly likely to become increasingly focused on delivery of environmental or public goods. This will create increasing pressure on farmers to generate return from the marketplace.

Other support schemes are available in Scotland, such as the Scottish Suckler Beef Support Scheme and the Scottish Upland Sheep Support Scheme. The suckler beef scheme supports beef suckler herds with the aim of sustaining the commercial beef industry in Scotland. It supports sustainable production which aids the environment and also recognises social benefits that arise from extensive beef suckler herds. The upland sheep scheme provides additional support to sheep producers who farm in Scotland's rough grazing areas and help farmers to maintain the social and environmental benefits that sheep flocks bring to those areas. Other schemes have been put in place in Scotland (such as the Beef Efficiency Scheme) which have had some success in delivering behavioural change across the industry.

Environmental requirements have also delivered change in behaviour, with different land designations restricting operations which can be carried out across a range of landscapes and specifical local areas of scientific interest.

9.2.2. Specific Incentivising Factors

Multiple individual factors influence farmer behaviour (categorised under the previously outlined high-level descriptors). The main incentivising factors are as follows:

9.2.2.1. Price

The majority of farmers are motivated by the selling price of their animals. As a result, if the price for a higher quality product is higher, many farmers will target this and will change breeding practices, management practices, feeding practices and health practices as a result of changes in price which are linked to these positive behaviours.

9.2.2.2. Profit

Many better farmers will look behind price to study the true cost of reaching the required standards. They will carry out a profit calculation, and it if is worthwhile, they will then target that type of production. It is important that any costs associated with compliance to the scheme are more than offset by the financial return from the programme.

9.2.2.3. Pressure to remain a member of premium schemes/farm assurance

Farm assurance is broadly recognised as essential, and if quality requirements were made in the scheme, most farmers will adjust to ensure that they remain members. It is however, essential that any changes made are achievable at a practical level, that the reasons for the changes are sound and that the costs are not prohibitive.

9.2.2.4. Guidance from environmental schemes

Environmental schemes can be used to deliver effective change through financially incentivising certain practices. The success of some of the environmental schemes shows that clear and targeted programmes which carry financial reward (or which enable compliance to legislative requirements) do change behaviour.

Awareness of the need for ongoing environmental improvement is growing amongst farmers, and there is growing interest in the application of practices and technologies which enable better compliance.

9.2.2.5. Peer pressure

Peer pressure in farming is very powerful. In general, if a quality scheme is to be delivered across Scotch Beef and Lamb, farmers need to be convinced of the benefits. However, not all farmers have to be convinced. If enough farmers take up the programme, eventually others will follow because they tend to follow what others do.

9.2.2.6. The opportunity to improve

For some farmers, the opportunity to be seen as better (either than those around them, or against international competition) is very powerful and any scheme must show how it could put Scotland at the top of the world in quality terms.

9.2.2.7. Pressure from legislation

Some farming activities are incentivised by legislation or policy, although ideally any quality scheme should be voluntary unless there is a very large advantage for the industry or economy as a whole.

It is worth noting that many quality advantages accrue from the sale of younger, quickly grown animals, and that these are also associated with a reduction in environmental impact.

These points of crossover are ideal candidates for legislation, or for inclusion within a farm assurance programme.

9.2.2.8. Messaging from representative organisations.

Messaging from the key representative organisations is very important. Organisations such as NFUS/NBA/NSA can be powerful allies in delivering industry progress and it is important to involve key organisations wherever possible. As a result, any proposed eating quality development and management system should be discussed in detail with these organisations.

The representative organisations are likely to strongly challenge the cost:benefit ratio of any proposed changes. This will force careful calculation of the benefits of any requirements against the cost (financial or resource) implications

of the change. A priority list of acceptable specifications could be drawn up and implementation procedures considered in conjunction with the representative organisations.

9.2.3. Specific Disincentivising Factors

During the execution of the study, a range of disincentives for farmers were considered in the design of the recommendations. In many cases, the disincentives are powerful as the incentives, if not more, and include:

9.2.3.1. A lack of understanding about the purpose of changes

If farmers do not understand the reasons for changes which are implemented, and the potential benefits of those changes, they are much less likely to buy into the programme. Consequently clarity is a key requirement of any changes which are made.

9.2.3.2. A lack of understanding about how to make the changes

If farmers feel that any required changes are unachievable or too difficult, they will not make them. Any scheme must be able to communicate practical management changes and the steps which are necessary to make those changes. In some cases, skills or knowledge training will be required and this must be easy to access for those who require it.

9.2.3.3. Costs of compliance are too high relative to the overall benefits

It is essential that the potential commercial (or other) benefits of the scheme exceed the perceived difficulty or cost of delivering against the new requirements. This means that careful estimates must be generated for the additional value which can be driven through the implementation of the quality programme.

9.2.4. Ensuring quality comes first

From a quality perspective, however, the main incentive over and above the higher base prices paid on the grading grid is through membership of the QMS Cattle and Sheep Assurance Scheme. Scotch farm-assured cattle and sheep receive a premium over non-farm assured stock. The premium for cattle tends to be larger than for sheep. Currently however, there are no significant quality criteria contained within the farm assurance scheme, meaning that to some extent the Scotch 'quality' reputation cannot be verified yet.

10. Part 3 - Recommendations for Implementing and Developing Eating Quality as a Measure of Quality Control in the Red Meat Sector

10.1. Introduction

To remain competitive in current world markets, it is important to differentiate from the current commodity led supply chain in the UK to a product that is of consistently high quality. The overall objective is the development of a system or methodology that ensures a more consistent product which meets consumer expectations. This currently does not exist within the Scottish industry.

The eating quality of red meat is of high importance in today's society. Consumers have good awareness that tenderness, juiciness, and flavour determine the overall eating experience[67]. However, tenderness is generally

[67] Kerry and Ledward, 2009

considered to be the single most important eating quality attribute associated with red meat[68], with consumers being willing to pay more money for guaranteed tenderness[69].

Research indicates that a poor eating experience is known to turn consumers off beef for up to 3 months[70], highlighting the importance of consistently delivering a product of the highest quality. This is particularly true for Scotch Beef which is strongly branded internationally. Despite the major advancements in meat eating quality that have been made in recent years through processes within the farm gate as well as within the abattoir, including animal handling, slow chilling, hip hanging and the dry ageing process, the industry is still producing a variable product with high levels of consumer dissatisfaction[71].

Addressing this issue is key to the future success of the Scottish red meat industry. Current payment systems have been developed to reward carcass yield, with little or no reference to meat quality.

Developments in meat quality assessment systems are necessary and, ideally should be driven and managed by QMS. The system needs to account for both meat yield and the quality of the meat, and should be constructed from a range of components. The overall aims are outlined below:

- The development of a system which enables QMS to deliver a product that obtains premiums for guaranteed quality.
    - Priority one: Ensure core supply meets a minimum QMS standard
        - The three-stage recommendation below outline how this could be achieved
    - Priority two: Bolt-on criteria can be added, for example, further categorisation into:
        - Production system
        - Meat with specific nutritional content (Omega-3) etc
- To develop a system which allows better utilisation of a high quality carcass
    - Additional cuts of meat to be used for producing steaks (topside, top rump etc.) and other premium products because they are identified as being tender enough to do so on an individual basis.
- To develop an eating quality system that delivers consistency and verification
    - This will require industry-wide collaboration and validation.

Birnie Consultancy appreciates that the current grading system is limiting and will present practical solutions to deliver impact, in both the short and long-term. The recommendations below around the development and management of eating quality in the Scottish red meat industry are set out in three stages;

1. Immediate actions (low-hanging fruit)
2. Meat Eating Quality Model Development (existing data)
3. Meat Eating Quality Model Development (new data)

10.2.Immediate Actions (low-hanging fruit)

The most immediate action would involve the creation of a new or significantly altered payment grid for prime cattle to deliver high eating quality product for the Scottish red meat supply chains. This grid would be designed to incentivise producers to deliver a product that increases the probability of higher quality, more consistent beef. Premiums within this grid would initially be heavily weighted on fat classification, but would take into account a range of other

[68] Koohmaraie et al., 2011
[69] Troy and Kerry, 2010
[70] AHDB, 2018
[71] Wim Verbeke, Lynn Van Wezemael, Marcia D. de Barcellos, Jens O. Kügler, Jean-François Hocquette, Øydis Ueland, Klaus G. Grunert, European beef consumers' interest in a beef eating-quality guarantee: Insights from a qualitative study in four EU countries, Appetite, Volume 54, Issue 2, 2010, Pages 289-296

components. The system would be built to allow for ongoing development, enabling the ongoing inclusion of additional quality indicators when it becomes possible to verify each practice.

Some of the low hanging fruit may initially seem difficult to achieve on paper, but if incentivised, uptake would be immediate and a dramatic improvement in meat quality could be realised.

10.2.1. Creation of a Quality Tiering System

The effective implementation of an eating quality system requires a method of communicating the quality to the consumer. A number of communication methods are possible but can broadly be broken down to either verbal messaging (highest eating quality, good everyday eating quality, everyday eating quality), or, more appropriately five star, 4 star, 3 star beef as well as beef which would be sold without a quality indicator.

10.3.Beef Quality Components

Improving the core product by delivering consistency in terms of age, weight, conformation, fat class and production method will dramatically improve the product delivered to the consumer. Cattle would fall into the New Quality Grid if they fall within the following criteria:

- Criteria 1: Steers and heifers
- Criteria 2: Under 16 Months of age
- Criteria 3: Fat class 4 or less
- Criteria 4: Under 360kg carcass weight

It should be noted that these are objective criteria, and they do not necessarily take into account the specifics of all production systems in Scotland. The application of these criteria may not be achievable under some systems, and the producer would need to make a judgement about the cost/benefit of changing their production system to meet any new quality standard.

10.3.1. Criteria 1: Sex of the animal

Steers and heifers would form the primary criteria selection in a quality management system.

10.3.1.1. Impact

Steers and heifers produce more tender meat than entire male animals. Collagen matures more quickly in bulls resulting in tougher meat. Additionally stress levels associated with pre-slaughter handling are also much greater in bulls and can result in tougher meat; associated with greater collagen cross-linkages, poor ultimate pH; increasing the risk of dark cutting meat, and poor shelf-life.

10.3.1.2. Implementation

Data on animal sex is currently collected at industry level and sex selection for quality would be easily implemented. The feedback from producers will be that bulls are more efficient (encouraging the production of bulls), but the quality penalty means that bull beef is not ideal for the highest quality tiers, but steers and heifers are. If a super-premium line was to be developed, this line may be restricted to female animals only.

10.3.1.3. Compliance/Integrity

Management of compliance will be relatively easy for Criteria 1. The only risk of any magnitude is that some farmers adopt late castration as a way of maximising animal growth performance while still enabling access to premium supply lines. However, late castration is relatively easy to detect at lairage, where any animal deemed to have bullish features (large neck muscle) would be excluded from the quality grid. Regular inspections should be implemented at farm and processor level to ensure compliance. Audits at farm level could be done through existing farm assurance schemes, with inspection of castration procedures being included.

10.3.2. Criteria 2: Age of the animal

An age limit of 16 months would form the secondary component of a quality management system. When combined with Criteria 1, this would mean that only steers and heifers below the age of 16 months of age would be included in the highest quality tier. Older animals can be included within subsequent, lower quality tiers.

10.3.2.1. Impact

Significant benefits will accrue as a result of the implementation of age limits. Reduced age to slaughter has the effect of reducing toughness associated with greater collagen cross-linkages, delivering a more tender and consistent product to the consumer, but also has the impact of increasing production efficiency[72]. Research has shown that reducing the age at slaughter by 3 months has a marked impact on all greenhouse gas production with a reduction in carbon footprint of approximately 15.0%. McCrabb and Hunter (1999) stated that reducing the age at slaughter will significantly reduce methane production.

Reducing the age at slaughter also improves production efficiency. Gerbens-Leenes et al. (2013), stated an efficiency increase; less feed/unit of meat, faster growing animals, and a reduced age at slaughter results in a decrease of beef production and water usage. These advantages will also reduce nitrate usage and improve land use efficiency.

Essentially the implementation of an age limit is a win-win component, conferring a range of benefits to the whole beef sector.

10.3.2.2. Implementation

Age data is currently collected at processor level and age limits could be easily implemented across this industry. Feedback from producers will be that this is difficult to achieve this, especially when meeting the Criteria 3 objectives of fat class 4 in continental steers. However, this can be overcome by proper diet formulation and system. An example of such a system is outlined below:

- Spring Calving Suckler herd (continental)
    - 15th March; calves born
        - 45kg
    - 1st August; Introduce creep feeder at grass
        - 200kg
    - 30th September; wean calves and offer ad lib concentrates at grass
        - 300kg
    - 31st October; house calves offer ad lib access to concentrates / very high quality TMR (specifically formulated for genotype)
        - 350kg
    - 1st May; commence slaughter
        - 650kg

10.3.2.3. Compliance

Compliance would be managed through existing systems within the processing sector. Data is already available to QMS and can be easily checked.

10.3.3. Criteria 3: Fat class

Only animals of fat class 4L and above would be permitted to enter the Tier 1 quality mark. Only animals of fat class 3L and above permitted to enter Tier 2 quality mark.

[72] P. Llonch, M.J. Haskell, R.J. Dewhurst, S.P. Turner, Current available strategies to mitigate greenhouse gas emissions in livestock systems: an animal welfare perspective, Animal, Volume 11, Issue 2, 2017, Pages 274-284

10.3.3.1. Impact

With the age restrictions, excessive subcutaneous fat will not be of great concern. Furthermore, the potential for more intramuscular fat (not always visible) has been shown to positively affect flavour, juiciness, tenderness and visual characteristics of meat, increasing overall palatability[73]. In young animals, fat levels won't be excessive enough to deter the health-conscious consumer.

10.3.3.2. Implementation

This data is currently being collected at processor level and would be easily implemented across this industry. The feedback from producers will be that this is difficult to achieve fat class 3 and above at this young age. However, this can be easily overcome by proper diet formulation and system.

10.3.3.3. Compliance

Compliance would be managed through existing systems within the processing sector. Data is already available to QMS and can be easily checked.

10.3.4. Criteria 4: Carcass weight

Only steers and heifers within carcass weight specification 270-360kg will be eligible for the quality grid. The reason for this is to drive more uniformity into the aesthetics of product in terms of size and steak weight specification, making it more suitable for more premium markets.

10.3.4.1. Impact

Introducing a carcass weight specification between 270-360kg for Prime cattle entering the quality grid will greatly enhance the primals which are marketable into premium markets due to the size of the cuts which result. Furthermore, it will greatly reduce the variability in terms of post-slaughter responses such as pH-temperature decline. This improved carcass response will produce a more consistently tender product with improved shelf-life.

10.3.4.2. Implementation

This data is currently being collected at processor level and would be easily implemented across this industry. The feedback from producers will be that Charolais and Limousin steers out of continental cows will exceed this carcass weight at 16 months. Therefore, it is key that they plan to have them slaughtered at an even younger age. A heavier carcass will produce loins that don't fit the modern consumers requirements (8oz steak, 18mm thick).

10.3.4.3. Compliance

Compliance would be managed through existing systems within the processing sector. Data is already available to QMS and can be easily checked.

10.4. Lamb Quality Components

Sheep systems in Scotland are highly diverse with upland and lowland production systems which are interdependent. These systems utilise the natural resources, with producers matching breed characteristics to the environment. Most of a lamb's diet is derived from grass, utilising land which can't be otherwise utilised for food production. Using its strengths and infrastructure, Scottish production systems have the potential to create a sustainable lamb production supply chain that delivers a high quality and consistent product. However, within this supply chain there are many challenges and inefficiencies that create variability in product quality.

[73] Miller, 2002

Again, creating a new payment grid for lambs would aim to deliver a premium quality product for the Scottish red meat supply chains. This grid would be priced to incentivise producers to deliver a product that increases the probability of higher quality, more consistent lamb. Premiums would be associated with the following criteria:

- Criteria 1: Female and castrate lambs
- Criteria 2: Fat class 2, 3 and 4
- Criteria 3: Under 9 months
- Criteria 4: 16 to 20kg

10.4.1. Criteria 1: Sex of the animal

Only female and castrate lambs would be eligible for Tier 1 classification.

10.4.1.1. Impact

Female and castrate lambs will produce more tender and more flavoursome meat. Meat from entire males can be tougher than that from any other sex types due to the possible influence of testosterone on collagen accretion[74]. Johnson et al. (2005), found that meat quality was lower in ram lambs than in females as shown by higher Warner-Bratzler shear values, higher ultimate meat pH values, and lower redness and lightness values. There is also considerable evidence that meat from young rams is more subject to off flavours than that from ewes or wethers[75].

10.4.1.2. Implementation

This data is currently being collected at industry level and would be easily implemented across this industry. Despite this known eating quality issue, there is a trend towards use of ram lambs to capitalise on the more rapid growth. However, this is a quality approach, and it is essential that ram lambs are discouraged.

10.4.1.3. Compliance

Regular inspections would be required at farm and processor level to ensure compliance. This could be done through existing farm assurance schemes and independent assessors.

10.4.2. Criteria 2: Fat Class of the Animal

Only animals between 3H and 4L in fat class would be permitted to enter Tier 1 quality classification. Only animals from 3L to 4H would be permitted to enter Tier 2 of the quality standard.

10.4.2.1. Impact

Fat (which is not always visible) has been shown to positively affect flavour, juiciness, tenderness and visual characteristics of meat, increasing overall palatability[76]. In young animals, fat levels won't be excessive enough to deter the health-conscious consumer. Evidence also shows that fat levels which are too high (>7.5% intramuscular fat) negatively affect eating quality, hence the upper limit on fat class.

10.4.2.2. Implementation

This data is currently being collected at processor level and would be easily implemented across this industry.

10.4.2.3. Compliance

Compliance would be managed through existing systems within the processing sector. Data is already available to QMS and can be easily checked.

[74] Sanudo et al. 1998
[75] Rousset Akrim et al. 1997; Young et al. 1997; Jeremiah et al. 1998; Oltra et al, unpublished data
[76] Miller, 2002

10.4.3. Criteria 3: Age

Bonus only for lambs under 9 months of age.

10.4.3.1. Impact

Strong odours and unfavourable flavours are associated with age, being more pronounced in ram lambs. Young et al. (2006) recorded that concentrations of the branched chain fatty acids 4 methyl octanoic and 4-methylnonanoic acids in fat (disliked flavours) were found to increase with age, especially in ram lambs. Sensory analysis determined that barnyard and sheep meat odours in fat varied with age, with a peak in sheep meat odour occurring for rams at about 300 days.

10.4.3.2. Implementation

This data is currently not being collected at processor level but could be implemented as a seasonal bonus to begin with (March to December).

10.4.3.3. Compliance

Compliance would be managed through existing systems within the processing sector. Data is already available to QMS and can be easily checked.

10.4.4. Criteria 4: Weight

Bonus only for lambs between 16-20kg.

10.4.4.1. Impact

It is important that producers deliver a product that meets consumer demand. One of the biggest issues within the lamb industry today is oversized legs. In fact, the current EUROP grading system is driving producers to supply an unsuitable carcass for the domestic retail market which represents about 70% of the market; one with a short loin and oversized legs. The loin is the most valuable part of a carcass and lambs predominantly being classified as E and U (top grades) for conformation have a shorter loin, e.g. the Texel breed has a lower number of, and shorter, thoracolumbar vertebrae than the majority of other breeds, and produces a high proportion of oversized legs.

10.4.4.2. Implementation

This data is currently being collected at processor level and would be easily implemented across this industry.

10.4.4.3. Compliance

Compliance would be managed through existing systems within the processing sector. Data is already available to QMS and can be easily checked.

10.4.5. Validation of Approach

This must centre around the formation of Demonstration Farms, that provide a platform for both evaluating new technologies or practices, and subsequently for communicating findings to other farmers. Typically on a demonstration farm, the farmer will receive additional support (technical and/or financial) during the evaluation phase, whilst additional monitoring, data collection and analysis may be conducted by scientific support staff.

It is also critical that the industry identify and promote the benefits associated with establishing a demonstration farm network to improve eating quality. Interventions and systems are evaluated in real-life situations, ensuring that findings will be readily transferable across the industry. Where any disadvantages are found, the farmer is often able to work with the scientific team in order to find a solution. During the dissemination phase, other farmers can see the intervention in practice, and are able to discuss any concerns they may have with the demonstration farmer. By providing both an evidence-base and reassurance to other farmers, the wider uptake of the new intervention is likely to be accelerated.

10.4.6. Meat Eating Quality Model Development

Developing a central industry database which incorporates all of the above parameters is essential. Collating this data into a single database will greatly enhance the ability to make informed decisions in improving meat quality. The development of this novel database will not only contribute to a meat-eating quality-based supply chain, but has the potential to provide highly practical information for beef and sheep farmers, which will allow management practices, production efficiency and profitability to be improved.

Within the Meat-Eating Quality Development section, both in terms of utilising existing data and new data, a key recommendation is to start collecting samples for ground truthing / validation. Ideally these sample would be collected on every animal or a subset of animals on a continuous basis.

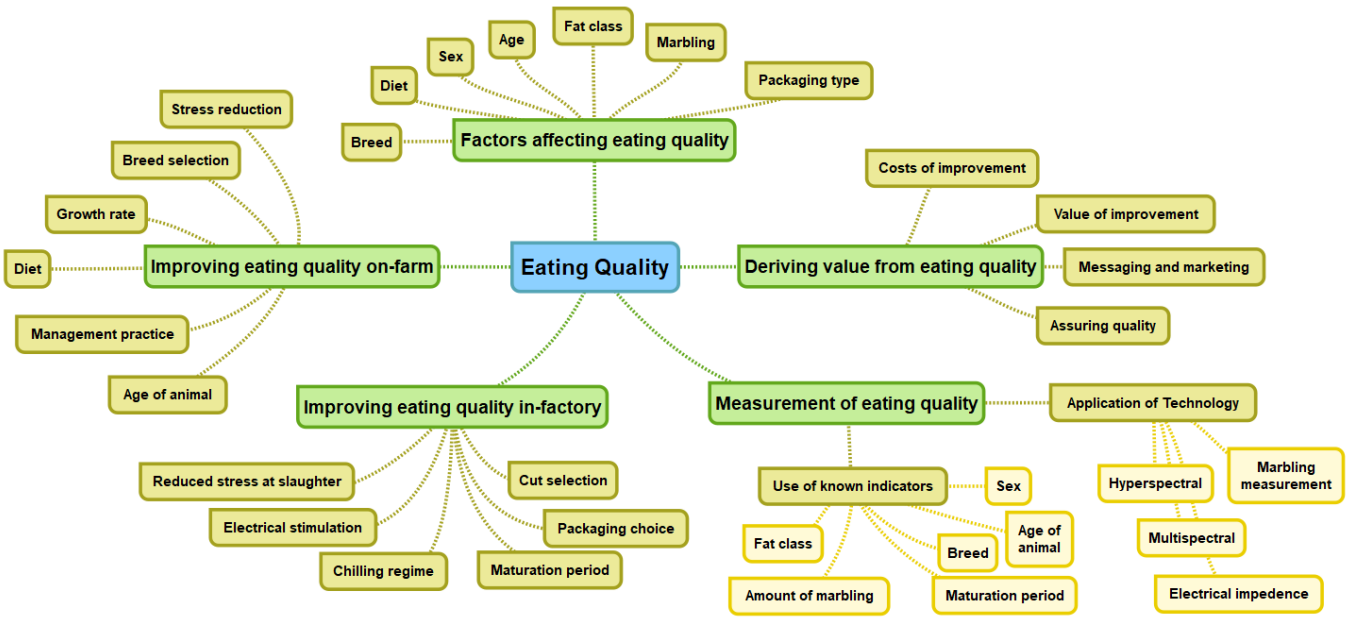
It is also the view of Birnie Consultancy that a Scottish Industry Meat Quality Model (SIMQM) should start with beef and that this should be used to inform other supply chains such as lamb and pork.

10.4.7. Existing Data

Meat quality refers to a wide range factors that describe the properties of meat. There are a multitude of pre- and post- slaughter factors that affect meat quality. However, every animal slaughtered in the UK today has a wealth of data associated with its identification that is currently not being used and could prove hugely beneficial in predicting meat-eating quality. Addressing this requires a holistic approach to identify the role of factors such as:

- Breed, age, weight for age, sire, dam breed, sex, health status (liver), transit time, transit distance, time in lairage, fat class, conformation, carcass weight, electrical stimulation, hanging method, chilling regime, maturation method, maturation period, etc.

Figure 9: Database framework



The overall objective within this section is to develop a meat quality model incorporating all existing data within the supply chain currently, as outlined in the figure above. Furthermore, the interaction between these variables is essential in explaining as much of the observed variation as possible.

Therefore, key questions include;

- What are the most important pre-slaughter factors affecting efficient beef production and subsequent meat quality?
- What are post-slaughter factors affecting efficient beef production and subsequent meat quality?
- What is the interaction between pre- and post- slaughter factors and how does this affect meat quality?

The potential impact of each pre- and post-slaughter factor has been outlined above. Furthermore, this also provides a platform for enhanced supply information that could be added to further strengthen the Scotch red meat brand. This would include data such as animal health data, antibiotic usage, etc.

10.4.8. New Carcass Quality Data

In terms of long-term objectives for the sector, developing a robust meat eating quality assessment / grading system will deliver huge gains for the Scottish red meat industry, especially beef. Such an approach will increase the eating quality and value of Scottish product, delivering expected value to consumers within the already highly regarded Scotch brand. The development of a meat-eating quality assessment system would allow differentiation from the current commodity-driven supply chain to a value-based supply chain whereby product is graded according to eating quality, and marketed appropriately with the aim of achieving high consumer satisfaction.

Following a review of the main meat-eating quality systems globally, we feel this system should be based on the principles of the Meat Standards Australia (MSA) model which includes a thorough and in-depth database for predicting eating quality. Furthermore, we recommend that the development of this system includes the development of a supply chain facing feedback system which benchmarks the supply chain and offers producers decision-support to further facilitate an increase in buy-in and meat quality enhancement.

Within the development of this model, stakeholder engagement will be a key element to the successful development and roll-out. The stakeholder engagement should place significant focus on developing relationships with processors and producers, with the formation of processor-led producer focus groups. These groups will enable information sharing between producers and processors and ensure that we have a common goal throughout the supply chain. Supply chain communication is necessary for participation, effect information gathering and dissemination, ensuring objectives, progress and findings are communicated effectively to the wider sector.

10.4.8.1. Scottish Industry Meat Quality Model Development

The development of the Scottish Industry Meat Quality Model (SIMQM) would involve the establishment of new data collection protocols for the industry. Whilst the initial implementation may be difficult, it has the potential to revolutionise the Scottish beef industry and deliver a product that consistently meets consumer expectations. The ability to deliver a consistent quality product of known eating quality ensures that value for money is always achieved, and research demonstrates that the consumer is willing to pay more for guaranteed quality.

It is recommended that the following new measurements be include within the development of a SIMQM model. Some of these are more difficult to achieve, and in consultation with the industry a staggered implementation schedule could be implemented.

1. Hanging method
    a. Achilles
    b. Tenderstretch
2. Marbling
    a. The level of intramuscular fat, which has a positive effect on eating quality. This is measured between the 10^{th} and 11^{th} rib
3. Rib fat
    a. Minimum rib fat of 3mm
4. pHu

    a. pH temperature decline is difficult to determine on each carcass so ultimate pH would be useful to eliminate dark cutters.
5. Eye muscle area
6. Fat colour
7. Meat colour
8. Meat texture
9. Meat firmness
10. Cut ageing

" SIMQM" Model Validation

The development of the SIMQM will involve much scientific analysis of data required. One of the huge advantages that the Scottish meat industry has is the expertise within SRUC in this area. The development of a SIMQM would require a large and robust database from which models can be developed. The aims will be:

- To collect meat quality measurements immediately pre-and post-slaughter, during chilling, and post-chilling.
- To collect meat samples for sensory analysis post-chilling.
    - These samples would be collected and sent to a central location for ageing and freezing. A factory protocol example is outlined below:
        - Chill carcass sides under a consistent regime across batches where possible.
        - Quartering to be carried 48hrs after slaughter and done between 10th and 11th rib.
        - Following bone-out, cut one 2.54cm steak from the rib eye end (anterior) of the sirloin.
        - Vacuum package the meat piece and label with ear tag no, carcass ID, date of slaughter, carcass side (RHS or LHS) and any other information of relevance.
        - Arrange for delivery.
- To conduct mechanical tenderness and sensory analysis on all meat samples.
- To create a data transfer methodology of information.
- To use the meat quality measures to create a model, capable of determining eating quality of an animal.
- To employ this model on a proof-of-concept basis to differentiate and batch cattle according to meat quality.
- To deliver a robust, on-line prediction of meat quality.
- To correlate the meat quality data with other industry databases such as genetics / genomics.

To facilitate model development, accurate input data is essential, and this will require the training of individuals to grade carcasses according to meat quality requirements. Within the model development phase, key outputs are required to allow appropriate correlations to be conducted as well as validation of the model. This will include mechanical meat quality assessment such as WBSF to assess tenderness, and sensory analysis such as consumer taste testing panels. It is our opinion that, ideally this should be linked to an industry-wide DNA system which is able to identify and track animals which are more likely to produce desirable high-quality meat.

"SIMQM" Model Impact

The main impact this model would have is the long-term and strategic improvement in Scottish red meat quality, through the development of a robust, value-based, meat quality assessment system. This will not only improve the reputation of the Scottish red meat industry but will also increase the knowledge base of producers, processors, and consumers.

The SIMQM would also drive improvements at producer level; having a tiered meat quality system will deliver a more informed and robust connection between producer and consumer goals. It will remove the current commodity-driven mentality and encourage producers to evaluate more closely the needs of their customers and deliver accordingly.

In delivering a value-based supply chain, consumers will receive a product that more closely aligns to expectation and one that matches closer to the price at the point of purchase. Furthermore, consumer awareness of red meat quality alongside more transparent and relatable labelling will enhance consumer perceptions of red meat and deliver higher levels of consumer satisfaction.

A final long-term impact will be the positive effect on environmental sustainability. Higher levels of consumer knowledge and satisfaction will ultimately deliver reduced wastage within the supply chain, further reducing the environmental footprint of red meat production.

11. Feedback from Industry

As part of the delivery of this report we engaged with a range of academics, commercial organisations, farm specialists and retailers to gain an understanding of the potential opportunity for Scotch Beef.

1) All retailers who fed back into the study confirmed that there was a desire for a system which is able to accurately reflect the eating quality of the meat:
    a. All retailers emphasised the value of enhanced quality.
    b. All retailers highlighted that beef eating quality was variable, and that lamb was less variable.
    c. There was a general belief that a product which improves the consistency of eating quality of meat will deliver increases in customer satisfaction and economic return.
    d. Practical experience of several of the retailers interviewed was that the creation of a genuinely enhanced product results in increased sales despite the increased costs associated with the product.
    e. It was generally recognised that the control of factors influencing eating quality in the factory has improved strongly over the last decade, but that control on-farm has not improved. The wide range of genetics and production systems were identified as being the major contributors to the problem.
    f. Butchers were less focused on the implementation of eating quality systems, as, to some degree they are able to manage the quality of their product though the selection of specific types of meat, the application of maturation techniques, as well as targeting of different cuts of meat to the needs of each individual customer. Many butchers are primarily concerned about cost, and want access to relatively inexpensive meat, although it was also acknowledged that an overall rise in quality would ultimately only be good for the industry.

2) Farmers have indicated a strong interest in the improvement of eating quality, for a number of reasons:
    a. The most usual reason was to enable increased economic return for the animals they produce. Many farmers recognised the value of enhanced quality.
    b. Farmers were also concerned about the reputation of Scotch Beef, and were keen for their sector to improve. However, many farmers were less concerned about this because they are unaware of the level of customer dissatisfaction.
    c. Some concern was expressed around the ability to monitor and police activity at farm level, and that there is the risk of other producers benefitting from access to markets for which they have not met the key criteria.

3) Processors expressed the most concern around the management of eating quality:
    a. They all recognise the importance of raised eating quality, and ideally would want to implement systems which enable this.
    b. The most significant challenge expressed by processors is not around the sale of the raised quality product, but in fact the sale (and potential devaluation) of meat which does not reach minimum quality standards.
    c. They believe that quality systems can be implemented, but that there are significant challenges behind the methods needed to ensure that the systems are correctly implemented.

4) Industry specialists and representative organisations:
    a. Discussion took place with a range of organisations working within the red meat sector.
    b. Almost all organisations recognised the importance of moving towards a system which manages eating quality and communicates this to the consumer.

12. Conclusions

12.1. Farm vs Factory Improvement

It is worth noting that, whilst the scientific literature carries different estimates of the relative importance of management of eating quality at farm level vs processor level. It is conclusive that both parties have a significant impact. This means that the delivery of consistently high eating quality is a joint responsibility. However, this does not mean that the task is equal. The authors of this report have spent decades working in both processing and farming, and it is our experience that the management of meat quality is much closer to ideal within the processing environment than in farming.

Processors have invested in electrical stimulation facilities, chilling, and maturation facilities. They can select on fat levels, or marbling. They can select on age, sex and breed. All of these characteristics are utilised within the Scotch supply chain to control quality. Not all are applied in every plant on every occasion, but most are. There is definitely room to optimise meat quality management in Scotch assured processors, and the use of an MSA style system would further improve the quality of output (although there would be a financial cost to balance against this). The implementation of an MSA system would be challenging, with additional systems, training and monitoring being necessary to ensure that it operates effectively. However, if the industry is serious about improving quality and enhancing the reputation of Scotch Beef, something like this is necessary. In an ideal world, it would be preferable to use technology to measure eating quality, but as we have shown earlier in this report, this technology does not exist in a commercial form, and where some technology is already used, it does not explain a large proportion of the variation (e.g. marbling levels explain about 5% of the variation). This means that any quality management system, by necessity, has to primarily be based on inputs (predictors) rather than measured outputs.

It is worth reinforcing at this point that there is almost no relationship between EUROP grid grades and eating quality, bar a small potential relationship to the fat class of the animal.

Variability at farm level is much greater that in the meat processing sector. There are a myriad of systems, genetic mixes, handling systems, transport systems, diets, weights, fat levels and more. The multiplicity of methods means that animals which enter the meat plant are highly variable. Whilst good practice in the factory can mitigate some of these, substantial differences exist between animals of different types, or from different systems. Gaining some form of control over what happens at farm level is essential if meat eating quality is to be substantially improved.

12.2. Considerations for Quality Development Plan

The following factors should be considered as an industry wide quality development plan is formulated.

1) Building and guaranteeing good eating quality is fully dependent on the successful control of multiple individual factors.

2) Some of these factors are at farm level, some at factory level, and different approaches will be needed to ensure and assure good practice.

3) The specific size of the impact of each of the factors is not necessarily quantifiable as eating quality is a factor of multiple components and interactions. However, it is known than control of these factors will raise the overall eating quality of meat in comparison to what is currently being sold. It will also - and perhaps more importantly – improve consistency of the product, which is regularly identified by retailers as one of the biggest challenges.

4) In-factory performance is generally better than on-farm performance, but improvements can still be made. The following components are key:
    a. Ultimate pH measurement of all carcasses
    b. Optimisation of pH temperature decline
    c. Optimisation of handling facilities

d. Optimisation of slaughter process
e. Optimisation of electrical stimulation
f. Implementation of appropriate maturation techniques and timescales (and balancing of this against the hip suspension/Achilles suspension techniques)
g. Animals to be processed in social groups
h. Selection of animals on sex, fat class and age to enable selection

5) On-farm performance is more variable and is much more difficult to manage:
    a. Much can be done to improve quality and reduce variability at farm level
    b. Verification of farm practice is difficult to achieve and can probably only be done effectively through farm assurance inspection against a set of input and output criteria
    c. A series of quality criteria can be established and inspected at either farm level, or through other verification methods. These components should include;
        i. Reduced rearing timescales
            1. Optimised health
            2. Optimised diet
        ii. Avoidance of a store period, where it has been shown that animals can lay down additional gristle
        iii. Breeding and/or feeding for increased intramuscular fat/marbling
        iv. Breeding or genetic selection for higher eating quality in general
        v. Optimised handling of animals to minimise stress
        vi. Ideally (although the literature is unclear on this), selection of animals with a calm temperament
        vii. Selection of animals for production of carcasses which have a higher proportion of high quality cuts (e.g. animals with long, strong loins)
        viii. Animals to be managed in social groups, transported in social groups and processed in social groups.

6) Tools must be implemented to help farmers to achieve the desired standards and to verify that the standards have been met. Tools for consideration should include:
    a. DNA sampling of all animals, with focused identification of animals with markers and genes associated with higher eating quality. Traceability and integrity benefits will also result
    b. Altered farm assurance, with three way information flow between farmers, farm assurance and farm suppliers, allowing verification of dietary claims
    c. On farm CCTV allowing spot inspection of welfare from a central source. It is appreciated that this would be highly unpopular with farmers and the benefits are consequently unlikely to outweigh the negatives
    d. Effective knowledge exchange tools to raise awareness of good practice amongst farmers, knowledge of how to implement these practices, and the value of implementation

12.3. Indirect Economic Benefit Associated with Improved Quality

All recommendations and observations on activity at farm-level and in processing are designed to illustrate optimum performance. Some of the recommendations made in this report may be incompatible with current farm systems and will be aspirational only. However, incremental improvements over a number of areas may only involve slight changes in management to realise significant benefits (i.e., reducing age at slaughter from 22 to 20 months, or improving handling facilities).

The diversity of Scotland's landscape necessitates a diverse make up of farm businesses and many of the optimum criteria may not be obtainable by some businesses, however there should be recognition that each business can use the information contained in this report to establish what optimum performance looks like on their holding in-line with their own priorities, ambitions, and the associated benefits of cattle production (i.e., biodiversity, culture, ecosystems or a key marketable property).

The remit of this report did not include determination of the exact economic advantage of improved eating quality. There are multiple examples across the UK and the rest of the world which demonstrate that improved quality does attract a premium from consumers, provided that they can be persuaded to purchase the product for the first time and that the eating experience matches their expectations. The potential direct economic advantage is taken as read.

However, it is also important to note that, whilst some of the farm level interventions will require some effort to manage, in many cases, the factors which enable good eating quality are also associated with high economic and environmental performance. These are hidden benefits, and it is to the advantage of the industry to draw attention to them:

- Quickly reared animals consume less feed per kg of carcass weight and are associated with a higher degree of tenderness.

- High health animals grow more quickly, have more tender meat, and are associated with lower antibiotic use, giving cost reductions and meeting Government targets around antibiotic resistance.

- Animals with calm temperaments are easier to handle, and are less likely to be stressed, reducing the likelihood of tough meat.

- Many of the traditional breeds have been shown to perform extremely well on forage based (and less expensive) rations, as well as offering generally higher eating quality. Data from feedlots (unpublished but known to the author) indicates that the cost per kg of gain for traditional breeds is, in many cases, much lower than for other more yield focused breeds. These systems will generally provide other benefits including those related to culture, ecosystems, and biodiversity.

12.4. Table of Recommendations

Recommendation	Timescale (S, M, L)
Representative sector targets	
Obtain industry consensus in Scotland regarding the desire to improve eating quality of red meat	S
Establish agreement to deliver the improvements over a ten year period	M
Agree and implement staged improvement targets, with a range of quality tiers. Farm and processor interventions should be considered	M
Design rules for farm assurance which will enable and ensure participation in the overall quality improvement programme	S & M
Measurement of quality baselines and improvements over the ten year period	M & L
Create a targeted marketing and communication programme to persuade farmers to take up best practice	M & L
Engagement with farmers to encourage uptake	S, M & L
Development and implementation of methods of communicating quality tiers to customer	M
Estimation of economic benefits of full implementation of quality programme	M
Processor targets	
Agreement of key components which impact meat quality at processor level and those which should be included across different tiers of the quality standard	S
Design and agreement of the components of each quality tier	S
Development and implementation of assurance programme to ensure adherence to the agreed quality practices	M
Discussion with processors around the alteration of the payment grid to incentivise animals with higher eating quality. Ideally this grid should be cost neutral, but this has to be balanced against returns which can be obtained for each category of product	M
Implementation of the new payment grid	M
Participation in quality measurement and feedback programmes	M & L
Farm targets	
Agreement of key components which impact meat quality at farm level and which can be audited and guaranteed. Additional components can be added over time	S
Design of a farm assurance bolt-on which can be used to assure that the practices are being implemented	S
Engagement with industry to progress implementation of quality management practices	M
Knowledge exchange to encourage uptake of the practices across Scotland	S, M & L
Demonstration of potential economic benefit of increased eating quality across the whole Scottish industry	S & M