beef such as Holstein beef. Breeds other than Japanese Black might be under evaluated than its real value to consumers. Beef marbling score has a significant weighting on the final quality grade and auction price. Furthermore, there is little information for consumers, because the JMGA grades are not usually displayed on retail cuts. However, recent trends show that the Japanese consumer is selecting leaner beef for everyday beef consumption. Consumer sensory testing would help to investigate these claims scientifically, as well as to explore the possibility of developing a Japanese beef grading system based on eating quality in the future.

In 2006, Rod Polkinghorne and his colleagues did sensory testing in Japan. The aims of this research is to evaluate the sensory categorization of beef by Japanese consumers, based on Meat Standards Australia methodology. Various cuts of beef, with a wide range of quality (from Australian and Japanese cattle) and three cooking methods (grill, yakiniku, shabu shabu), were evaluated by 1620 Japanese consumers in Tokyo and Osaka. Four muscles from 36 Japanese and 87 Australian carcasses were used in this study. Consumers rated each sample for four sensory attributes, then selected one of four grades, based on the quality of the beef within each cooking method. The distribution of the Japanese consumer MQ4 scores showed a clear distinction between grades, with the majority of scores being included within the boundaries of each grade (Polkinghorne et *al.*, 2011). The MQ4 score allocated approximately 64% of the samples to their correct consumer grades. The MQ4 score showed potential to be used as a tool in developing and monitoring a consumer focused grading system that is able to predict Japanese consumer satisfaction of individual beef cuts prepared by different cooking methods. The proportion of samples assigned to each grade was similar for Japanese and Australian consumers for yakiniku and shabu shabu cooking methods, however Japanese consumers assigned lower scores to the grill samples (Polkinghorne et *al.*, 2014). In terms of the MQ4 boundary scores between grades, these were very similar for both Japanese and Australian consumers across all cooking methods. In terms of the weightings for the four sensory traits, juiciness was more important for Japanese consumers than Australian for grill and shabu shabu cooking methods. Flavour had the highest weighting for both consumer groups. This study showed that a beef description system based on the MQ4 score, with some adjustments to the weightings and cut-off values, could be useful in describing the eating quality of beef for the Japanese consumer.

XIV. DEVELOPMENT OF THE MEAT STANDARDS AUSTRALIA (MSA) INDEX AND THE ROLE OF GENETICS

The objective of the study presented by Peter McGilchrist, Rod J. Polkinghorne, Alexander J. Ball and John M. Thompson was to produce a single number that depicts the eating quality of a beef carcass. The Meat Standards Australia (MSA) grading model accurately predicts the eating quality of 39 individual cuts in a beef carcass from commercial inputs available at grading (Watson et *al.*, 2008b). Each cut receives a meat quality score (MQ4) between 0 and 100, based on a prediction and combination of 4 traits; tenderness, juiciness, flavour and overall liking (Watson et *al.*, 2008b). The MQ4 score for 39 individual cuts is also predicted for up to 6 cooking methods for each muscle (Watson et *al.*, 2008b). The MSA model is complex due to the non-linear impact of different model inputs between cuts and the diversity of the Australian cattle demographics and production systems. The MSA system has also shown that no single indicator cut like a striploin can be used to truly reflect the eating quality of the carcass, which is why MSA predicts the eating quality of 39 cuts and not just 1.

The potential eating quality of a carcass is of interest to producers as they can use feedback to evaluate the improvement in eating quality due to various factors like: investment in new genetics; different suppliers of feeder cattle; difference between seasons or years and other production factors. However to date, carcass feedback to producers is in the form of individual measurements for carcass traits like carcass weight, ossification, MSA marbling score, rib fat, hump height or *Bos indicus* content, ultimate pH, gender, hormonal growth promotant, milk fed vealer and saleyard status. The impacts of all these factors on the eating quality of 39 different muscles in the body are not linear due to the complexity of muscle biology. Due to the non-linear nature of factors impacting eating quality, producers cannot assess individual carcass traits assessed by MSA graders to evaluate the eating quality of a carcass. Hence the MSA index was created, which is a single number calculated for each carcass.

The MSA index is an average of the MQ4 scores for the 39 cuts in the carcass for the most commercially utilised cooking method. Each of the 39 MQ4 scores has a fixed weighting for their proportion of the total cut weight of the 39 muscles. The proportion is fixed as Butterfield and May (1966) show that muscle distribution is largely a result of the functional stresses being placed on the muscles. All beef animals regardless of breed and whether they are raised in a feedlot, or on pasture, place similar functional stresses on their muscles by standing, walking and resting. Whilst different breeds (and also individuals within a breed) may differ widely in conformation, Butterfield and May (1966) suggest this has little impact on the functional stresses placed on individual muscles and hence the proportional muscle distribution within the carcass. The results from a bone-out of 40 cattle showed no variation between individual animals in muscle distribution as a proportion of the whole between high and low muscled cattle. However in cattle with a myostatin mutation, the proportional weights of some cuts did vary, but the proportion of the Australian herd carrying myostatin mutations is very low.

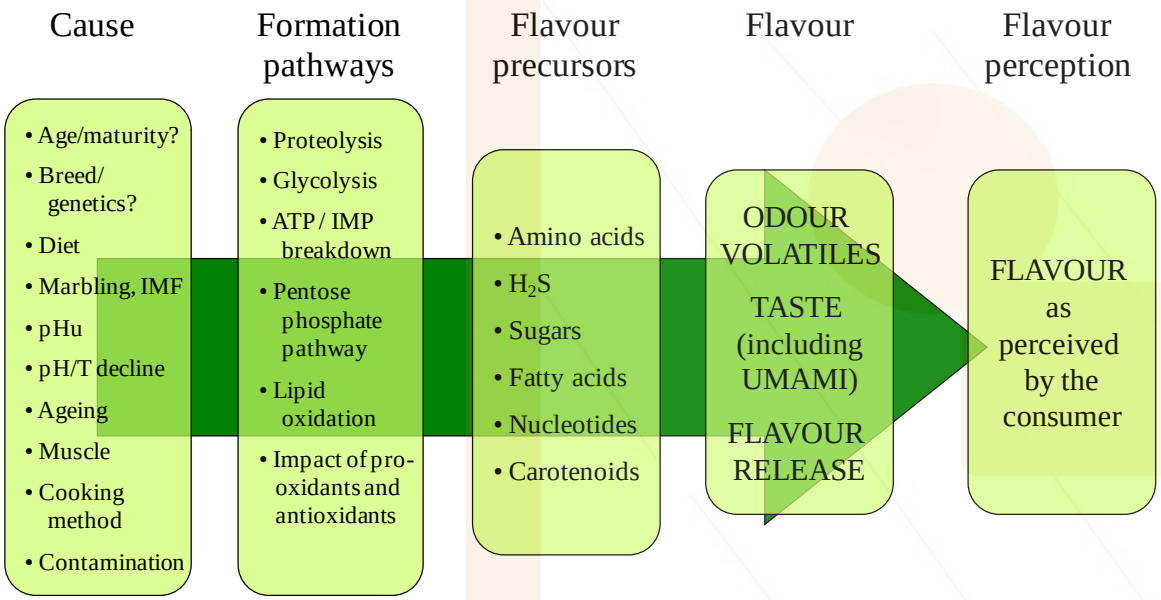
Across the Australian herd, the MSA index generally ranges between 30 and 80 and can be utilised to analyse eating quality over time within a production system, across production systems and to benchmark producers. It can also be used by producers to accurately measure the impact of production factors like hormonal growth promotants, marbling score or the percentage of *Bos indicus* on intrinsic eating quality of cuts delivered to consumers. The impact of selecting sires with higher genetic breeding values for marbling, growth, carcass weight and fatness on the MSA index is currently being evaluated across large data sets. This will be very useful information for producers to help evaluate the impact that sires will have on the eating quality of their progeny.

XV. INCORPORATING FLAVOUR RESEARCH INTO CARCASSE GRADING FOR EATING QUALITY

Linda Farmer indicated that previous studies have shown that the Meat Standards Australia (MSA) grading system is excellent at predicting the eating quality of Northern Ireland's beef (Farmer et *al.*, 2010). Nevertheless, for NI consumers, the model was better at predicting tenderness than flavour and the consumer quality score was predicted better by flavour liking than by tenderness (Farmer et *al.*, 2009). Research on the MSA system in other countries (R Polkinghorne, personal communication) has shown that this latter is also true of consumers in other countries.

Flavour is the combined effect of odour and taste, caused by volatile compounds and water-soluble components, respectively. The odour compounds are generally formed during cooking by the reaction of 'flavour precursors' present in the raw meat. The formation of flavour arises through the known biochemical and chemical processes occurring post-slaughter (Figure 1). These various substances contributing to flavour are usually identified and quantified using chromatography and mass spectrometry methods. Many odour compounds are present at very low concentrations, requiring specialist techniques, and methods involving the analysis of more abundant 'marker compounds' have been developed. These techniques can provide useful insights into the factors affecting flavour, as determined by consumers (Farmer et *al.*, 2012).

Figure 1: Summary of the mechanisms of formation of flavour in beef



While analytical instruments are reducing in size and becoming ever more sophisticated, they are not yet suitable for analyses on-line in a meat plant. Therefore, the challenge is to use the understanding gained from instrumental analyses, combined with consumer and descriptive studies, to allow flavour quality to be incorporated into a grading system. Recent studies (Legako et *al.*, 2015; Legako et *al.*, unpublished data) have shown that the consumer perceptions of flavour arising from differences in muscle, intramuscular fat or ageing are reflected in differences in volatile odour compounds, taste compounds and precursors. Further research is needed to link meat biochemistry and chemistry with flavour formation and to allow flavour quality to be predicted and matched to consumer preferences.

XVI. INTERNATIONAL BEEF EATING QUALITY LANGUAGE

The concept of an international beef eating quality language is no longer new and recent updates were described by Rod Polkinghorne and Jerzy Wierzbicki. Most descriptive beef languages used globally have probably always been thought to fill this role through describing carcass attributes, raising systems and cuts. In fact work over the past 20 years has established that the traditional carcass based systems, while grouping carcasses into groups of similar appearance and describing cutting lines, are relatively ineffective in describing actual consumer satisfaction with the resulting meal.

Attempts to overcome this deficiency have taken many forms including the Meat and Livestock Commission blueprint in the United Kingdom, PACCP Pathways in the USA and the initial Meat Standards Australia (MSA) pathways in Australia. The MSA system established a new approach in directly utilising untrained consumers as a measurement tool, moving over time from validation of production "pathways" to developing eating quality prediction models.

The MSA developed consumer testing and data collection protocols, supported by software routines, have been extensively utilised in Australia and in collaborative studies in South Korea, Northern Ireland, USA, Japan, the Republic of Ireland, South Africa and France. Further significant

independent studies utilising the protocols have been conducted in Northern Ireland, USA, New Zealand, Poland, the Republic of Ireland and France, with France and Poland also conducting collaborative studies. The individual data also include extensive linkages to other global language standards including EUROP and USDA. Consequently a considerable amount of consumer and consumer measured data exists in very similar format capable of being combined for analysis and potential application in describing and predicting beef sensory response across global consumer populations.

A primary aim should be to demystify beef at consumer level by facilitating the use of simple contemporary food product terms that clearly indicate an expected meal outcome rather than an elaborate set of often misleading cues that relate to source animals and cuts.

As beef is a globally traded product it is sensible to, as far as possible, develop and adopt a common language base. This can facilitate collaborative research, dramatically reduce the cost of developing consumer based prediction approaches and simplify product description in trading and retail environments.

The UNECE Specialized Section on Standardization of Meat, which currently administers a global beef language standard, has noted that further consultation is needed regarding development of a collaborative way to collect and record information on the development and keeping of protocols or procedures for consumer testing, potential meat grading inputs and data for research purposes. A working group led by Poland as lead rapporteur has further considered this issue (United Nations Economic Commission for Europe, 2015) and will report back in late September, 2015.

The focus of this is research collaboration which it is hoped will facilitate more efficient work across scientific and industry groups and an enhanced understanding of consumer populations and the interaction with livestock and production systems. Data analysis and tactical research collaboration will determine the extent to which consumer and cattle populations are similar or differ when corrected for typical grading inputs including gender, carcass weight, age, ossification and marbling. This in turn will inform the extent to which a common base may be applicable for the prediction of consumer satisfaction and the degree to which such predictions may need to be adjusted across consumer groups. It is also important that agreed standards to describe potential grading inputs be supported by formal standards and systems for training and monitoring their use.

It is hoped the principal of collaborative work facilitated by an agreed language standard will be readily accepted. The devil, as always, is likely to be in the detailed application with prior research funded by a range of industry and private entities and with differing degrees of support from a number of Government agencies. Consequently we need to begin considering models that can facilitate collaboration and potential ultimate commercial application.

We propose that a staged approach be considered utilising the following principles:

1. That a common cloud based database structure be developed with the format published and made available to interested parties.
2. That software routines be published in open code that facilitate and automate research trial design, data accumulation and the execution of consumer testing and related data collection. These routines should interact with the standard database structure.
3. That agreed ontology be developed and published to facilitate the consolidation of data from local databases, utilising local language and descriptive terms where necessary, to a common collaborative master global data cooperative.
4. That local groups retain ownership and control of their own country, organisation or company data to the extent desired through their local version of the standard database.
5. That data, or data fields, be approved for amalgamation in a collaborative global “data cooperative” / database. Confidential data such as company or producer names could be removed or blind coded within this process.
6. That approved data be uploaded through standard procedures to the global research data cooperative with ontological adjustment in the upload procedure.
7. That the proportion of valid records (to a minimum data standard) contributed by each partner be continually recorded.
8. That researchers be granted free access to the global data cooperative under a collaborative research structure with key researchers meeting through a steering committee to coordinate priorities and peer review results.
9. That the opportunity to develop consumer prediction models that share a common base and to clarify where local variations are warranted be pursued within the structure.
10. That a knowledge base of global consumers be progressively assembled through contributing studies to facilitate accurate prediction of sensory response within local populations and cooking styles.
11. That common terminology be adopted to describe consumer satisfaction facilitating trade communication and supporting beef recording, trading, reporting and commercial branding activity.
12. Should commercial application of prediction models developed from the global data cooperative be desired they could be delivered by an independent not for profit group and made available to all parties via web based processing at equal cost per carcass graded to all industry participants within a country. The GS1 commercial structure used for international product codes may be a useful model.
13. That revenue from any commercial application be applied firstly to cover the operational cost with a further proportion distributed to the research data contributors in proportion to their current share of the records held and contribution. This share would change over time as individual providers contributed additional research data and value.

The proposed structure is advanced for discussion and aims to provide a balance between the immense value of developing a global capacity to deliver consumer satisfaction through simple common description and the uneven contribution of research partners and other industry groups who do not or have not contributed to the research effort but have an interest in commercial application.

The collaborative research component must by definition proceed before any common commercial application occurs, or perhaps needs consideration, allowing time for alternative strategies or business models to be debated.

Development of an international eating quality language is an ambitious but very worthwhile endeavour of critical importance to the global beef industry. Delivered in full it is believed to be a fundamental game changer through firmly placing consumer satisfaction as the focus of beef description.

XVII. PERSPECTIVES OF EATING QUALITY GRADING FOR BEEF AND LAMB: SCIENTIFIC AND INDUSTRY VIEWS IN CHINA

Professor Qing-Xiang Meng and his collaborators (Hai-Ling Luo, Yan-Ling Li, Li-Ping Zhao, Li-Ping Ren) described the perspectives of eating quality grading for beef and lamb in China.

As reported by the Statistical Data (Chinese Agricultural Yearbook, 2015), China had 68.39 million of inventory beef cattle and 6.73 million tons of beef output. Average beef produced was 141 kg per slaughter with 5.1 kg beef consumption per capita. Meanwhile, the inventory of sheep and goats was about 300 million with 4.28 million tons of both sheep and goat meat. Because of a strong demand for beef and lamb products by Chinese consumers, the market price of beef and lamb has been increasing in recent years. In order to meet such a demand of beef and lamb for the consumers, cattle, sheep and goat operations have tried to increase beef and lamb production by feeding more animals. In order to guarantee market supply and stabilize commodity prices, the Chinese government opened the channel for the importation of beef and lamb products from other countries, such as Australia, New Zealand, Canada, Argentina, Brazil, Uruguay, Chile and Costa Rica. However, there is another problem for smuggling of beef and lamb with an estimated amount of more than 3,000,000 tones illegally introduced to China from neighboring countries, such as Burma, India and Vietnam.

Although the national standards of carcass grading for beef cattle and sheep and goats (Beef Quality Grading, 2010; Lamb and Mutton Evaluation and Grading, 2002) were issued by Chinese central government, these standards were not applied well in practice. Some new progress has been made in the quality grading of beef and lamb in China. A laboratory for beef sensory quality evaluation has been established at China Agricultural University. Studies have been undertaken in this lab for samples of meat from local breed beef, Holstein calf meat and yak meat as well.

MSA-based techniques were also successfully tried in the lab using beef and lamb products with both hot-pot (Huoguo) and Tieban cooking ways. Based on the MSA procedure, Chinese beef and lamb could be graded for their eating quality that may be used for making decisions of their market price. Through collaboration on an international project led by Dr. Pethick of Murdoch University, Australia, we will compare sensory scores between Australian, Chinese and USA untrained consumers using lamb and yearling sheep meat. After that, beef products will be used for comparing their eating quality by the MSA system (Polkinghorne et *al.*, 2008b).

XVIII. EUROBEEF, A EUROPEAN THEMATIC NETWORK ON IMPROVING OFFER AND DEMAND IN BEEF PRODUCTION IN EUROPE

Lastly, Koenraad Duhem, Linda Farmer, Isabelle Legrand, Christophe Denoyelle ; Jean-François Hocquette and their collaborators described the ambitions of the Eurobeef network in case of funding by the European Union.

The European Union is ranked third in the world for beef production with 7.7 million tons of carcasses. 40% of this production is produced by beef/suckling herds, which are principally located in France, Spain, United Kingdom, Ireland and Italy. European beef farm systems contribute significantly to beef production but also to an interesting land use, in the sense that areas utilized by suckler cows are mountains and Mediterranean areas or permanent grasslands that cannot be exploited for other types of food production. Cow-calf production occurs in rural areas and participates to a certain extent in maintaining economics and social life in the countryside, contributing to sustainability. Beef production is also well developed as a complementary activity in dairy farms.

Unlike its main competitors, Europe has a wide variety of beef farming systems. As a consequence, meat may originate from different categories of animals and beef meat is not a standardised product at the retailer stage. This diverse production makes the industry very complex.

The EU consumption of beef reached a high in 1985 with 25 kg, but from then steadily declined to 17 kg. Beef is an expensive meat and the quality offered at retail (tenderness, juiciness, flavour…) often doesn't meet expectations. Some countries like Australia have kept their beef consumption steady in recent years, partially due to quality programs (Griffiths and Thompson, 2012).

Beef consumption is not only driven by intrinsic quality (the characteristics of the product itself), but also by extrinsic qualities (animal health and welfare, food safety, nutritional value of beef, environmental impacts …) (reviewed by Hocquette et *al.*, 2014a). An assessment of beef supply chains found around Europe through standardised methods would allow the identification and development of the most sustainable strategies (United Nations Economic Commission for Europe, 2015; Watson et *al.*, 2008a, 2008b). Any discussion of these complex issues would require all stakeholders to take part.

Under the Societal Challenge 2 of the Horizon 2020 program, the topic ISIB-2-2014 proposes the development of thematic networks, aimed at closing the gap between research, innovation and practitioners. Eurobeef has been proposed as such a thematic network in the European value chain of beef production; it is led by "Institut de l'Elevage", (France), partnered by INRA (France), Agri-Food and Biosciences Institute (NI, UK), Polish Beef Association, Centro Ricerche Produzioni Animali (Italy), Teagasc (Ireland) and UECBV (EU).

The project is intended to enhance organisational innovation along the whole beef value chain. The purpose is to better address the offer and demand issue at several steps of the value chain to make the European beef industry more sustainable and competitive.

The objectives of EUROBEEF are to respond to the following questions:

"How can farmers, their organisations, slaughter-houses, meat processors and retailers all work together to supply the

European regional and International markets and consumers' meat demand, while improving sustainability of the beef industry?" The response lies in the organisation of a dialogue of all stakeholders. The project will focus on the consumer view and go 'upstream' along the supply chain to include production systems.

The Eurobeef Network will cover 15 regions in 8 countries. In each of the regions concerned, EUROBEEF will address 3 issues:

•"How can consumer's demand be addressed?" This issue is about the piece of meat ready to consume in the plate (not about the carcass quality or the animal characteristics including its breed)

•"How can producers and their organisations build up their offer with regard to the market's needs?" Here the issue concerns the best combinations of breeds/husbandry techniques to produce quality animals in each region according to market availabilities.

•"How can the whole beef chain be more sustainable in order to match with societal expectations?" This wider issue deals with citizens' concerns regarding social impacts, environmental services and economic viability of the beef chain.

The core themes will be:

•Networking (Work package 1)

•Regional Comparison of Beef Supply Chains (Work Package 2). Mapping the European supply chain and assessing the implications of the observed patterns.

•Eating Quality of Beef (Work Packages 3,4,5), comprising three parts: Determination of the industry real needs regarding eating quality and consistency, evaluation of existing scientific knowledge on eating quality and quality standards, identification of tools and mechanisms to meet the needs of the European beef industry to optimize eating quality

•Sustainability assessment of beef production (Work Package 6). Improving the economic and environmental performance of beef cattle farms by defining and disseminating of the most promising management tools to monitor technical, economic and environmental performance

•Development of a Stakeholder Driven Research agenda (Work Package 7). Identifying the research, development and innovation needs of the beef sector in the EU and selected regions

•Communication: the results will be communicated in the network and to a larger audience of interested stakeholders.

OVERALL DISCUSSIONS AND CONCLUSIONS

A key feature of the MSA system is that the sensory response, or final eating quality assessment, is estimated as a weighted score of tenderness, juiciness, liking of flavour and overall liking using untrained consumers. In other words, the MSA system is focused on estimating the eating quality response of the population who purchase meat. Australia has a large data set of consumer responses to beef that has allowed the development and commercial application of the MSA muscle x cook prediction tool. Data sets using common protocols have now been developed in several collaborating countries and regions (France, Korea, Poland, Republic of Ireland, New Zealand, Northern Ireland, South Africa, United States of America) and most of this has occurred due to simple 'organic' collaboration between like minded scientists with some commercial input. Across the countries, the data has clearly showed enormous commonality in how consumers respond to beef in particular. Furthermore much of the data has been converted into peer reviewed journal papers meaning there is little if any residual intellectual property to protect. Finally, speakers from France, Poland, Republic of Ireland and Northern Ireland (and published work from Korea and South Africa) agreed that the base MSA model is an adequate tool for predicting the eating quality of beef for 'their' consumers. However extra precision would be possible if some adjustments were made for issues like (i) alternate production systems that are not included in the MSA prediction model (e.g. beef and dairy bulls, dairy cows) (ii) subtle consumer differences between countries and (iii) new cooking methods (e.g. hot pot, degree of doneness).

It was recognized that the value of a combined global database and cooperative development of eating quality standards and prediction routines far outweighed the sum of individual isolated databases due to the largely complementary nature of existing data and the benefit of cross linkages at animal and consumer level. Further benefits of collaborating in research work and merging data under a data cooperative function were greatly improved efficiency and reduced cost for individual partners and the benefit of access to multiple research facilities and direct involvement of a larger pool of scientific expertise.

With this background the following recommendations have evolved:

1. The palatability web site be housed and managed by MSA (http://palatability.une.edu.au/drupal/user) with research partners encouraged to add content and stimulate dialogue.
2. The existing Australian MSA dataset format be adopted as a base for development of a more contemporary cloud based database structure (or content management system) with appropriate organisation, standardized ontology conversion and administration to provide a secure environment and facilitate merging of data from multiple partners within a data cooperative.
3. The MSA consumer testing and trial design software routines linked to the current database structure be utilized as a base for an open code software package that can be integrated with the new database structure. This should be developed to facilitate experimental design, and automate file and label creation for product collection, fabrication to consumer samples and allocation of muscles/meat portions/labels to consumer sessions by collaborating researchers.
4. That a consultant (Rod Polkinghorne) in collaboration with Meat & Livestock Australia coordinate and manage the data base development and trial design software routines. This is to include the transfer of existing data to individual country versions, and associated software routine development on behalf of the collaborating countries to ensure that existing data remains compatible and, where desired and approved by individual data contributors, be readily merged within a data cooperative. Cost recovery for this work to be negotiated.
5. That collaborating countries be offered the opportunity to upload 'like' consumer and related animal,

carcass and objective data into the data cooperative with a negotiated position on the use of both the uploaded and other cooperative data developed by the working group.

6. That the working group develop operational guidelines for research use of the data and extend this to a commercial model for the development of commercial 'MSA' like sensory prediction models.

7. The concept of Global Guaranteed Grading (3G), which has been presented in Milan, be embraced where shared Australian and international data sets be combined within a data cooperative to produce in the first instance country specific eating quality prediction models.

8. Meat & Livestock are open to the MSA prediction model being released by negotiation to collaborating countries using the 3G principal described above.

9. International collaboration on lamb eating quality using the MSA protocols is welcomed in a similar manner to beef.

10. Objective carcass grading for predictors of eating quality is a high priority, especially for lamb.

11. Ultimately systems need to evolve so producers are paid on the basis of eating quality of a muscle x yield of that muscle as planned in the Eurobeef network submission.

12. Of great importance is the development of smart tools for simple reporting across the value chain, especially to include producers.

In order to drive and focus the proposed recommendations, it was agreed to establish a working group of current collaborating countries that would be open with respect to new partners. The working group will meet 1-2 times yearly via teleconference or alike and strive to arrange the next workshop in association with the ICoMST 2017 conference in Cork, Ireland.

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