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Qualité de la viande pour un avenir durable

Qualité de la viande pour un avenir durable - Qualité sensorielle, normes et solutions innovantes pour le commerce

Mots clés : qualité sensorielle, normes, commerce

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Cet article est un compte-rendu partiel du workshop organisé par la Commission Economique des Nations Unies pour l'Europe concernant les présentations relatives à la qualité de la viande.

Résumé

Cette conférence a été organisée par la Commission économique des Nations Unies pour l'Europe (UNECE) en collaboration avec les organisateurs du Congrès International sur la Science et la Technologie de la Viande de 2019 (ICoMST). Ce workshop international de l'UNECE a porté sur la qualité des viandes, les normes de qualité, les derniers développements en matière de qualité sensorielle, les solutions innovantes pour un commerce durable de la viande, la sécurité alimentaire, la traçabilité des technologies de la viande et la blockchain ; de même que sur des solutions plus durables pour réduire les pertes et gaspillage dans le secteur de la viande. Les présentations des orateurs sont disponibles sur http://www.unece.org/index.php?id=51442.

Abstract: Meat Quality for a Sustainable future – Eating quality, standards and innovative solutions for trade

This meeting/workshop has been organized by the United Nations Economic Commission for Europe (UNECE) in collaboration with the organizers of the 2019 International Congress of Meat Science and Technology (ICoMST). The international UNECE meeting/workshop was focused on sustainable meat quality and standards; the latest developments in the area of eating quality; innovative solutions for sustainable meat trade; food integrity, traceability of meat and blockchain technologies; as well as sustainable solutions to food loss/waste prevention in the meat sector. Presentations of speakers are available on http://www.unece.org/index.php?id=51442.

INTRODUCTION

After a general introduction by Ms Liliana Annovazzi-Jakab, Head of the Agricultural Quality Standards Unit of the United Nations Economic Commission for Europe (UNECE), the Chair of the UNECE's Specialized Section on Standardization of Meat, Mr. Ian King, introduced the work of the Specialized Section highlighting the role and importance of the meat standards and the eating quality work. He noted that UNECE standards for meat provided trust, facilitated fair international trade, prevented technical barriers to trade, defined common trading language for seller and buyers, promoted high quality sustainable production and created market transparency for buyers and consumer. International best practice, standards, guides and training can help countries to ensure consistent quality and establish trusted and sustainable trade relations.

I. MEAT QUALITY FOR A SUSTAINABLE FUTURE – MAKING DATA FINDABLE, ACCESSIBLE, INTEROPERABLE AND REUSABLE

The ontology projects and the FAIR (Findability, Accessibility, Interoperability, and Reusability) data principles were presented by Jean-François Hocquette.

Animal husbandry research is focusing on the selection of animals that should be: 1) Efficient in terms of the processing of food resources to limit their use at the maximum and to reduce emissions to the environment, 2) Robust and adaptable towards climate change and towards a wide range of livestock breeding systems and 3) Able to generate a high yield of quality products to meet consumers' needs in taste, health and nutrition and citizens' expectations concerning for instance animal welfare (Hocquette *et al.*, 2012).

In this context, providing phenotypic information, which is accurate, reliable, repeatable and comparable across countries or laboratories, is critical to compare data and to gain a better understanding of the relationship between genes and phenotypes. Unfortunately, in the specific case of beef eating quality, sensory data with panellists are poorly comparable between countries or across slightly different cooking protocols (Gagaoua *et al.*, 2016). More generally, it is extremely difficult to combine different sources of phenotypic data from multiple origins, partly because of the variability in the methods of data acquisition (Hocquette *et al.*, 2011). However, large databases are very useful for modelling and predictive biology. Such an objective involves the construction of a coordinated network of research and professional facilities and a common language with shared definition of unambiguous animal traits and of methods to assess them.

To this end, the 'Animal Trait Ontology of Livestock' (ATOL, http://agroportal.lirmm.fr/ontologies/ATOL) project has been initiated with the objective of defining precisely the phenotypes of interest for farm animals. Then, it will be necessary to combine an environmental information system related to animal husbandry and associated methods to capture the phenotypic differences between animals. More generally, many vocabularies and ontologies are produced to represent and annotate agronomic data. However, those ontologies are organised in different formats or structures. Therefore, a common platform has been designed to receive and host them, align them, and enabling their use in agro-informatics applications. This is the AgroPortal, an ontology repository for the agronomy domain http://agroportal.lirmm.fr/), which in fact re-uses the biomedical domain's semantic tools and insights to serve agronomy (Jonquet *et al.*, 2018).

Furthermore, data sharing is highly supported by the scientific community and this implies to improve any infrastructure supporting the reuse of scholarly data. A diverse set of stakeholders including academia, have designed together a set of principles called the FAIR Data Principles, which are guidelines to encourage data sharing. Four foundational principles (Findability, Accessibility, Interoperability, and Reusability) were defined to guide data producers and publishers thereby helping to maximize the added-value gained by data sharing (Wilkinson *et al.*, 2016).

As a practical example of these scientific challenges, the SmartCow project leaded by INRA (https://www.smartcow.eu/) has the following objectives: 1) Unification of methods and protocols across Europe for cattle research, 2) Unified ontologies across Europe, 3) Contribution to the interoperability of data, 4) Management of the continuous flow of data collected or produced by Research Infrastructures and other cattle projects and 5) Improvement of cattle phenotyping abilities of research infrastructures.

In conclusion, phenotyping is a poor partner in integrative biology and the rate-limiting step in genomic selection. Indeed, unlike genomics (focused on DNA), phenomics is concerned by many targets and different methods. This needs first the development and use of ontologies. Another challenge is storage, sharing and analysis of comparable data across laboratories and countries. This will favour the development of international infrastructures to better achieve these goals.

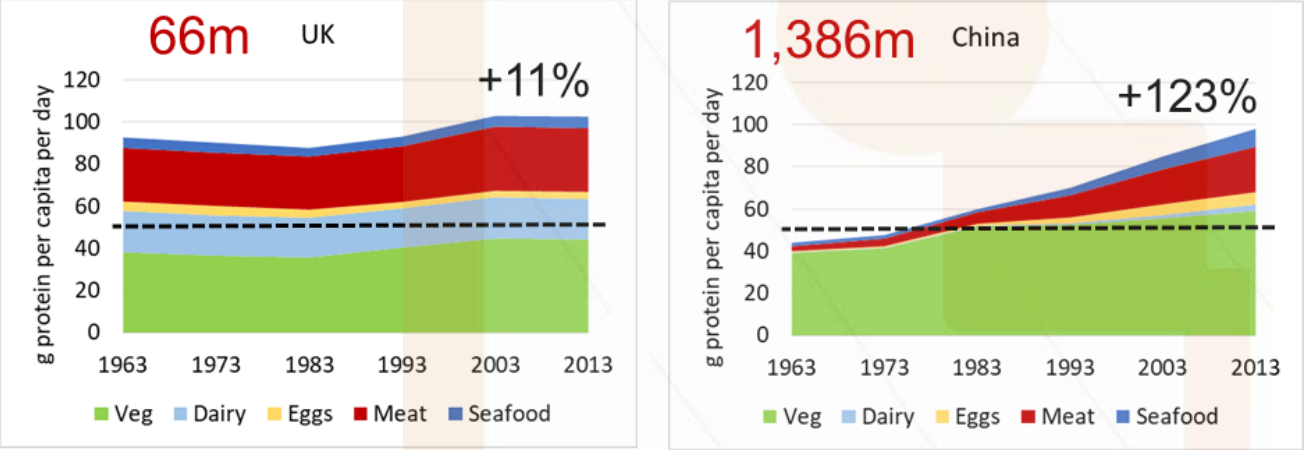
II. MEAT QUALITY FOR A SUSTAINABLE FUTURE – EATING QUALITY

Challenges for the meat industry - is eating quality still important?

Linda Farmer opened this session by outlining the challenges for the meat industry and asking "Is eating quality still important?". There is considerable negative media coverage on meat consumption, focusing on the impact of meat production on the environment and the reported health risks arising from consumption of meat products and, possibly, red meat. Consumers have responded by changing consumption habits, with an increase in vegan, vegetarian and "flexitarian" diets. In addition, meat can be of variable eating quality (Farmer *et al.*, 2016) and consumers respond to negative experiences by delaying repeat purchase by 1-3 months (AHDB, 2016).

Despite these reports, there are good nutritional reasons for consuming some meat as part of a balanced diet. It provides not only a source of protein but is also an important source of vitamins A, D and B12 as well as essential fatty acids. There are also strong cultural traditions for meat consumption across Europe. There, however, is a huge disparity in the consumption of meat between different countries, with consumption increasing in China and other countries as incomes rise (FAO). The UK and others in Europe and America are eating considerably more than the recommended protein intake. The world will be unable to produce enough meat for everyone to eat a "Western diet".

Figure 1. Intake of protein in UK and China, 1963 – 2013 (FAO), showing population (red) and recommended protein intake (---) as well as % increase in protein intake.



Despite recommendations (Westhoek *et al.*, 2011; Buckwell and Nadeau 2018; Willett *et al.*, 2019) that the Western world should reduce meat intake and increase intake of food from vegetable sources, it is unlikely that most people will eliminate meat from their diets completely. However, where consumers do respond by eating meat less frequently, it is likely that their expectations of quality will rise.

The European meat industry is considering how to respond to these challenges. They may address decreasing consumer demand at home by finding new markets in those parts of the world where consumption is increasing. They may make better use of all the co-products from meat production, reducing waste. They may also diversify their product range, catering for smaller portions and "mixed meals" that incorporate plant-based foods. However, as consumers become increasingly aware of alternatives to meat consumption, the industry will also need to ensure that the eating quality of their products consistently meets expectations.

Taking Europe forward – Goals and vision for the International Meat 3G Foundation

As explained by Jerzy Wierzbicki, much of the work in beef science was internationally collaborative as meat scientists sought to develop appropriate science based approaches to support industry in improving the consumer experience. Critical steps were the development of rigorous test protocols and expression of consumer sensory standards as a 4 variable meat quality (MQ4) score, combining tenderness, flavour liking, juiciness and overall liking. This is the basic principles of the Meat Standards Australia (MSA) grading scheme. This led to the realization that accurate prediction of an individual beef meal result needs to assign an outcome to cooked individual meal sized portions rather than a generic carcass description. A further fundamental decision was to accumulate data from all related experiments and commercial product evaluation in a common database utilizing consistent description to enable issues to be evaluated over multiple disparate base studies.

Formal MSA international collaboration began with consumer studies in South Korea (Thompson *et al.*, 2008), and Northern Ireland (Chong *et al.*, 2019), and were followed by further projects in USA (Polkinghorne *et al.*, 2007), Japan (Polkinghorne *et al.*, 2011), Ireland (McCarthy *et al.*, 2017), France (Legrand *et al.*, 2013), South Africa (Strydom *et al.*, 2019) and, later on, in New Zealand (Garmyn *et al.*, 2019), USA (O'Quinn *et al.*,

2018), and Poland (Pogorzelski *et al.*, 2020). More recently, new studies were developed in the UK and Wales in the past year.

Many of the research teams and individuals have concluded that for maximum global beef industry benefit and research efficiency, it would be highly beneficial to pool data for analysis and to develop further industry applications. The various consumer studies had also established that global consumer groups were more similar than different with very similar sensory response despite cultural differences (Bonny *et al.*, 2017, 2018).

Central to these efforts was the use of common protocols and measurement (Watson *et al.*, 2008a, 2008b). With the adoption of common sensory test protocols, consumer data was complimentary with many animal and carcass traits also common or readily translated. Others, such as marbling and ossification were not used in some regions, and led to work with the UNECE Specialized Section on Standardization of Meat to establish and document extensions to the UNECE Bovine Language Standard. A working group with Poland as lead rapporteur developed recommendations for beef grading, which were subsequently accepted and now provide a formal base for data aggregation and conversion where appropriate.

A not for profit Foundation, the International Meat Research 3G Foundation (https://imr3gfoundation.org/), was subsequently incorporated under Polish law to provide a practical structure to facilitate scientific collaboration, data storage and utilization and to provide a platform for commercial application. Formal structures include a Management Council charged with legal responsibility for governance, business functions and delivery of commercial activity and a Scientific Reference Group with responsibility for scientific standards, collaboration and peer review.

A major project is DATABank which is establishing a cloud based data storage and management system that can provide secure and confidential data storage for members and facility to pool data for agreed purposes as desired. Supporting largely open source software is being expanded to provide easy access for researchers or students to assist with trial design and application aligned to standard protocols to ensure compatibility. Considerable effort is being made through the ontology working party to ensure standardized description and linkage to other international standards such as ICAR (International Committee for Animal Recording) or ATOL (Animal Trait Ontology of Livestock). A data analysis technical group is foreshadowed as data is accumulated and made available for scientific investigation and potential development of eating quality prediction models with the capacity to relate consumer populations to alternative production systems and regions.

"Eating Quality Research -Training Assessors"

The International Meat 3G Foundation has responsibility for training human graders in carcass chiller assessment in Europe, and potentially further regions, and is collaborating with AUS-MEAT to ensure uniform application of the UNECE standards, based on the MSA grading scheme, including human grader correlation through a computerized quality assurance program (OSCAP). As explained by Ian King, training courses were run in Wales and France in 2019 (https://www.youtube.com/watch?v=4blnbdMZAjA) and will expand further in conjunction with supporting applied Meat Science courses for industry participants. It is anticipated that the Foundation may provide access to eating quality prediction models for beef grading on a commercial basis to encourage uniform consumer based standards within a cost effective framework. Above all long term benefit will accrue from rigorous scientific collaboration related to providing a sophisticated consumer focus and understanding to support long term beef industry sustainability and relevance.

III. GRADING FOR EATING QUALITY – UPDATES

French management of beef eating quality

Mr. Christophe Denoyelle described how the French meat sector is organized in order to provide a higher quality meat to French consumers using the "Label Rouge" quality sign.

France has the first cattle herd in Europe with eighteen million point two heads of cattle, more than 20% of the European herd (revue de Hocquette *et al.*, 2018). Meat production is a major economic sector in France with more than four hundred thousand direct and indirect jobs. France presents a wide variety of cattle breeds. This is a major asset for French meat production, which provides different kinds of carcasses for the different commercial channels.

The "Label Rouge" quality sign (INAO, 2017) is based on technical specifications defining production systems from breeders to retailers. An official technical note defines the minimum criteria to obtain the "Label Rouge". More specifically, each "Label Rouge" meat is based on the commitment of a chain including breeders, slaughterhouses, butchers and supermarkets. Each label is led by a defence and management organization that is responsible for the functioning of the "Label Rouge". Each "Label Rouge" is controlled by a certifying body. "Label Rouge" requires a total individual traceability from the animal to the steak. Each animal has a passport with different information. Each animal has also two tags in each ear with the same national number to ensure the correspondence with the passport. This traceability system provides consumers with assurances on the reliability of the compulsory labelling info given to every single piece of beef on sale: its origin.

This system has been implemented since 1978. "Label Rouge" is based on the strict respect and control of the specifications all over the chain. To guarantee a premium quality, the meat is analysed by consumer taste panels according to the meat and fat colour, tenderness, odour, flavour and global satisfaction. At the moment, 16 different beef "Label Rouge" exist all over France.

What about the future? In 2018, the French meat sector represented by INTERBEV decided to increase the volume of label rouge production up to 40% of French meat production. New specifications for example on feed, welfare, and the introduction of new quality measurement for marbling will be added. To conclude, the French meat sector has a long experience of meat quality management. Its approach is based on the use of well-known factors that influence eating quality. Tomorrow, other approaches could be complementary to decrease the chances of a consumer having a negative eating experience with "Label Rouge" products.

BeefQ – application eating quality models to advance beef grading in Wales

The BeefQ - Beef Eating Quality Project was presented by Nigel Scollan. It is a pre-competitive collaboration between international research and industry partners, to develop an eating quality assessment system for Wales. The system being developed is based on eating quality assessment protocols implemented successfully in other countries, such as the Australian Meat Standards Australia (MSA) system (Watson *et al.*, 2008a, 2008b). The project consists of four main strands: a survey of PGI Welsh Beef carcasses submitted for slaughter; development of a model for predicting beef eating quality in Wales; training for industry personnel in eating quality assessment and meat science and finally engagement with industry stakeholders to promote the concept of beef eating quality assessment and develop a strategy for taking the BeefQ outputs forward in Wales post project. The survey, to describe and quantify the population of beef carcasses from animals born and reared in Wales, comprised the eating quality grading (using UNECE protocols) of 2090 carcasses. Four cuts from 90 sides of beef surveyed were selected for testing with 1200 consumers. Consumers were presented with seven samples of grilled steak and asked to score them according to taste, tenderness and juiciness. This data forms the basis for developing an eating quality prediction system for Welsh beef. The training of processing plant personnel and industry representatives in the various aspects of eating quality grading has not only been valuable for building eating quality assessment expertise in Wales but has enabled practical farmer focussed demonstration and discussion events on eating quality. This type of activity, along with broader industry stakeholder engagement is raising the profile of, and discussion around, the potential benefits of eating quality prediction for the Welsh Beef sector. Establishing and maintaining good relationships with companies processing PGI Welsh Beef has been integral for the successful delivery of BeefQ activities. The consumer events, hosted by Further Education Colleges, provided an unforeseen legacy for BeefQ by allowing the project team to engage directly with the farmers, chefs and consumers on beef eating quality.

Ovine eating quality and yield standards for the future

The Australian red meat industry is working to increase the transparency of trading along the supply chain by improving the valuation of carcasses. To achieve this, the Advanced Livestock Measurement technologies (ALMTech) project presented by Honor Calnan is developing objective technologies to measure Lean Meat Yield percentage (LMY%) and eating quality. Currently, the Australian lamb industry values carcasses based largely on carcass weight, with penalties applied at the extremes of fatness measured by GR tissue depth (11cm from the midline over the 12th rib). However, GR tissue depth is an unreliable predictor of carcass LMY% measured using medical computed tomography (CT) (Williams, Anderson *et al.*, 2017). In the beef industry, carcass LMY% is estimated by measuring the fat depth at the P8 site or over the loin muscle at the quartering site. However, as in lamb, these single-site fat measures are poor predictors of CT LMY% (Williams, Jose *et al.*, 2017). While the Meat Standards Australia (MSA) system values beef on eating quality, a similar individual carcase grading system does not exist for lamb eating quality.

Multiple technologies are being developed in the ALMTech project to improve the prediction of LMY and eating quality in beef and lamb. To enable the application of these measurement technologies, 2 new traits are being established as the calibrating standards – CT LMY%, and chemical intramuscular fat percentage (IMF%). All technologies developed to predict LMY% in livestock or carcases will be trained on LMY% measured using a medical CT as the gold standard measurement. Training all new technologies on this common trait enables the direct comparison of their performance. Hence, industry can consider the precision and accuracy of a measurement system with other factors such as cost or footprint. Additionally, CT LMY% can predict retail cut weights with high precision in lamb and beef, meaning technologies trained on CT LMY% can use these established relationships to produce cut weight predictions. Using CT LMY% as the calibrating standard for all devices enables a common language to be used across the supply chain, for LMY% measures to be fed back to producers and geneticists as CT LMY%, and to be fed forward into boning rooms as CT LMY% to predict retail cut weights. This language is already used in industry, with Livestock Data Link feeding lamb and beef carcass data back to producers as CT LMY%, while Sheep Genetics produce a CT LMY% sire breeding value.

The second trait being established is Chemical IMF%, given the strong positive relationship between IMF% and consumer eating quality (tenderness, flavour, juiciness and overall liking) of lamb meat (Pannier *et al.*, 2014). The gold standard method for determining IMF% is a laboratory based near-infrared (NIR) method, calibrated on soxhlet IMF extraction. All technologies being developed to predict IMF or marbling will be trained on Chemical IMF%, allowing the precision and accuracy of the devices to be effectively compared and for information to be relayed along the supply chain using a common language.

Standards are required for CT LMY% and Chemical IMF% to be established in the Australian lamb and beef industries. The ALMTech project has formed an industry calibration working group to develop standards that will comprehensively describe the methodology of the traits such as the medical CT scanner settings or the sampling protocols for Chemical IMF% measurement. The standards will also serve as standards for any devices predicting these traits; detailing the measurement device, its calibration requirements and considerations such as processing influences, timing of measurements and potential auditing requirements. These standards will be essential to the successful transition of the Australian supply chains to transparent value-based trading of lamb and beef.

Guaranteed Global Grading (3G) – The Pathway to Implementation

As explained by Rod Polkinghorne, all beef industry revenue, regardless of sector, originates from the ultimate meat consumer. The consumer determines value, which is a relationship of the eating experience and price. Given this critical relationship, any successful and relevant beef grading system must accurately and simply describe an individual meal experience (Grunert *et al.*, 2004, Grunert, 2006).

Consumers understand value and apply value judgements to purchasing decisions as diverse as choosing what class of airline travel they purchase, the car they buy, and the fuel they buy for it. Each of these products, and in fact all successful consumer goods, are offered within a clear, simple and precise description system.

The mission is to deliver the equivalent in a clear, simple and accurate description of a beef meal outcome. This requires a reversal of beef descriptive language flow: rather than providing the consumer with information relating to cattle breeds, raising systems, cuts or processes such as ageing the objective is to simply describe a guaranteed meal experience for a meal sized portion of beef, and to deliver this experience through industry application of science and control of the many biological and mechanical factors that complexly interact to create the experience. We must guarantee the experience, not expect the consumer to deduce it from a series of often unrelated or marginally related cues (Polkinghorne and Thompson, 2010, Biddle *et al.*, 2016, Polkinghorne 2018).

Over the past 20 years, a number of researchers in different countries have utilized Meat Standards Australia consumer testing protocols to evaluate beef of many types and qualities produced through multiple environments (Thompson *et al.*, 2008, Legrand *et al.*, 2013, Polkinghorne *et al.*, 2014; review by Hocquette *et al.*, 2014). The additive value possible through standardised description and pooling of data has led to the creation of a not for profit research foundation, the International Meat Research 3G Foundation, building on several years of development through the auspices of the UNECE specialised section of meat (https://imr3gfoundation.org).

The Foundation is now established and is engaging in several areas of work to enable and encourage development of systems and data to facilitate development of beef grading technology and training and its' commercial implementation. The capacity to store and, where desired, pool data for analysis is being created by the Foundation DATAbank project including planned augmentation by open source software to facilitate widespread utilisation. The Foundation in conjunction with AUS-MEAT, the Australian standards organisation, is also equipped to deliver training in meat grading with initial courses delivered in Wales and France in 2019. Further Foundation sub-committees are developing ontology and flavour chemistry standards.

These important steps provide a framework for international scientific collaboration in development of eating quality prediction models and associated training together with operational systems for commercial implementation.

IV. INTEGRATED SOLUTIONS – INSTRUMENTAL MEASURES OF EATING QUALITY

Objective methods for meat quality in Australia - Almtech project

Within Australia, the Advanced Livestock Measurement Technologies (ALMTech) project is developing objective technologies to measure lean meat yield percentage (LMY%) and eating quality. This is in response to industry demand for increased supply chain efficiency, enabled by trading carcases based upon their true value - as reflected by the amount and quality of saleable meat.

Technologies measuring LMY% were presented by Graham Gardner. They range from simple tissue depth measurements such as microwave, to more complex technologies that quantify composition across the entire carcass, such as dual energy x-ray absorptiometry (DEXA), computed tomography and whole carcass 3-dimensional imaging systems. Technologies measuring eating quality range from RGB and hyperspectral camera systems that image the cut surface of the loin, through to computed tomography and nuclear magnetic resonance systems that require no carcase quartering.

Implementing a new technology requires considerable planning, engagement with industry, and generation of supporting evidence. In this case, we can use the Australian industry roll-out of DEXA as a case in point. This system has been shown to maintain a high level of accuracy and precision in predicting carcass composition in beef and lamb (Gardner *et al.*, 2018), particularly when compared to the existing industry standard using GR tissue depth (Williams, Anderson *et al.*, 2017). Recent installations at abattoirs across

Australia have enabled the development and testing of a calibration system to ensure that consistent predictions are acquired across sites. This is the pre-curser to an industry-wide auditing system based upon scan values for synthetic phantoms that will ensure consistency in measuring this trait.

One of the vital next steps for the Australian lamb industry is the creation of an industry language defining whole carcase composition – likely that measured using a medical CT scanner. Currently the industry trades upon the simple-to-measure trait of GR tissue depth, despite its relatively poor association with carcase composition (Williams, Anderson *et al.,* 2017). Creation of this new trait requires substantial evidence to demonstrate the reliability and repeatability of this measure, and its linkage to commercial cut weights, the ultimate trait of economic importance. Crucially, this will require industry consultation and support for this trait to become legislated. Once in place, other technologies measuring LMY%, such as DEXA, can be accredited for predicting this trait, and the associated industry auditing systems established. We envisage that an independent industry body such as AUSMEAT would assess the compliance of technologies against these auditing standards.

Further development work is currently underway to diversify the outputs from the DEXA system. It has been trained to predict commercial cut weights, and these will soon be implemented as predictive outputs from the DEXA systems installed to-date. This will provide processors with the opportunity to benchmark the expected yield of their boning-rooms, and enable carcase sorting prior to fabrication to reduce waste and optimally meet market specifications for cut weights. Optimisation algorithms are being developed to enable this carcase sorting, optimally fitting carcases to target markets on the basis of maximized profit. This approach fits the predicted cut weights to market specification for each cut, market value and volume, and the in-plant cost of procuring that cut. Work is also under-way to determine the capacity for DEXA to predict eating quality. It is well established that LMY% is a negative predictor of eating quality, an immediate output from DEXA, but there may also be potential to determine carcase maturity as a separate trait to LMY%, providing further potential to implement an eating quality prediction system for lamb.

With respect to lamb producers, we are working with supply-chains to provide more detailed feedback from the DEXA. This will enhance the capacity of producers to meet the carcase specifications demanded by the supply chain, through tailoring their genetic and management decisions on-farm. Ultimately, this should facilitate value-based trading for whole carcase composition.

In summary, the provision of technologies through ALMTech research, and the creation of new traits for these technologies to predict will enable the Australian industry to trade carcases based upon their true value - as reflected by the amount and quality of saleable meat. Ultimately, this will provide transparency in trading across the supply chain, and enhanced efficiency.

Application of REIMS to Meat - underpinning assessment of Integrity and Quality

Mass spectrometry techniques have been associated with meat safety and quality testing for many years; they allow the chemical compounds found in meats to be identified and quantified. Lipid analysis and screening for veterinary residues are two key applications of mass spectrometry for meat analysis, but in recent years, mass spectrometry has increasingly been used by those who wish to identify and quantify compounds responsible for meat taste, smell and texture.

The mass spectrometry techniques most associated with meat analysis are those, which include a gas or liquid chromatography separation process prior to the mass spectrometer. These techniques, although mature, have costs (both in time and money) and it has become desirable to achieve methods of undertaking mass spectrometry which reduce or eliminate sample preparation and chromatography costs.

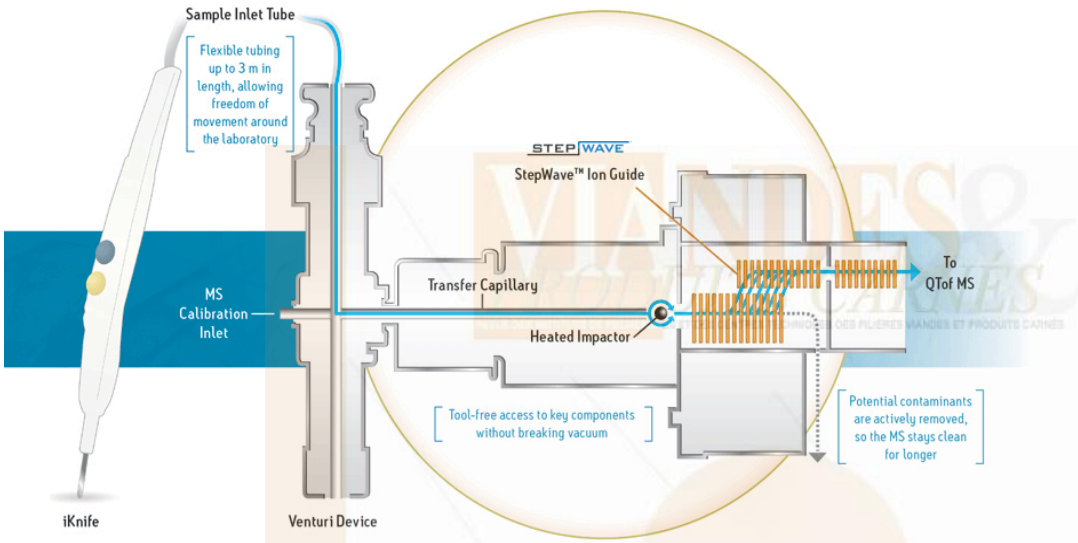
Rapid evaporative ionisation mass spectrometry (REIMS) is one mass spectrometry approach presented by Nicholas J Birse, which fulfils this requirement. REIMS is an ambient mass spectrometry technique, enabling sampling directly from the tissue specimen for analysis with no requirement for sample preparation or chromatographic separation (Verplanken *et al.,* 2017).

REIMS works by means of a diathermy probe, which passes an electric current through the cellular material, causing cell lysis by a process of Joule heating. The cell lysis process produces an aerosol rich in lipids from the cell membrane, which are aspirated into the mass spectrometer by a venturi vacuum system. Ionisation occurs on a heated kanthal coil within the ion source, over which the aerosol passes (Figure 2). The mass spectrometer used is typically a high-resolution time-of-flight instrument, such as a Waters G2-XS, operating in negative ionisation mode.

The resulting spectrum produced covers a mass range of m/z 100 to 1200 with two distinct groups: fatty acids between m/z 200 and 500, and phospholipids between m/z 600 and 1100. These mass ranges are used to build chemometric models, using material of confirmed authenticity or with specific attributes, against which unknown samples can be compared. The lipid profile of the specimen tissue is the result of a combination of factors, but most strongly affecting the profile is animal species, breed and diet. The lipid profile can also be affected by the administration of veterinary products, and by gender, further widening the types of testing REIMS can be used to undertake (Balog *et al.,* 2016).

REIMS has been demonstrated as a technique, which can be used to detect economically motivated substitution of meats, where a higher value product is replaced by a lower value product, in adulteration, where a lower cost product, such as animal by-product, is used as a bulking agent, as a way to assess carcasses for quality issues, such as boar taint. There has also been work undertaken to develop REIMS as a method to predict the eating quality of lamb meat, and to determine the authenticity of complex poultry production systems (Gredell *et al.,* 2019).

Figure 2: Principles of the REIMS methodology



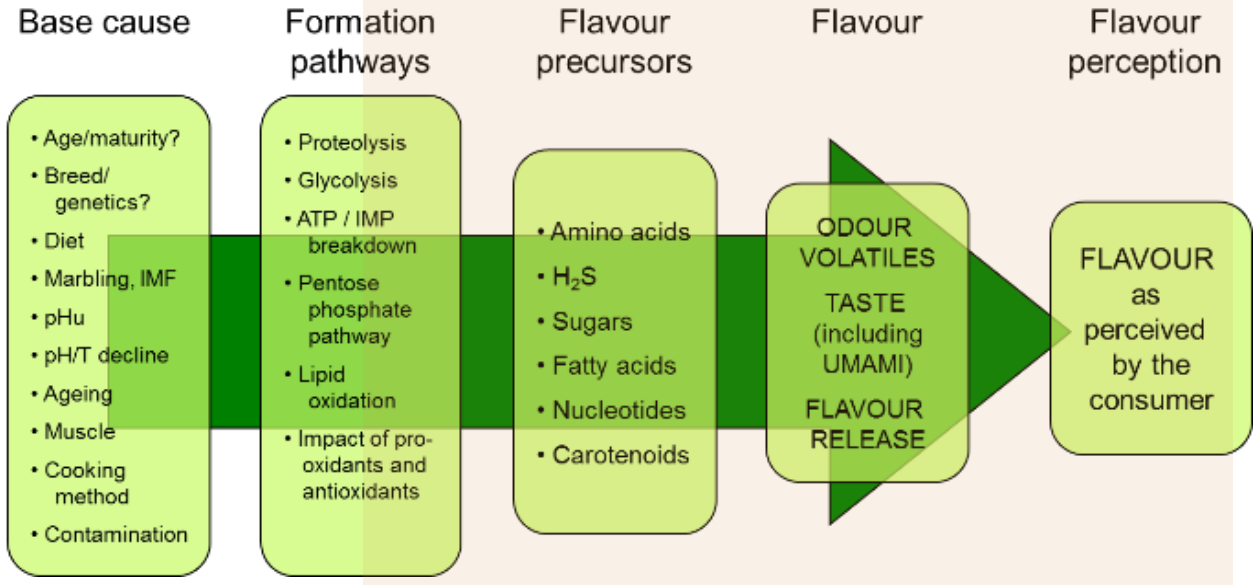
The use of REIMS as a technology to rapidly assess carcasses for boar taint has moved from laboratory to factory, with the deployment of a commercially orientated REIMS system in an abattoir environment. The speed at which REIMS is capable of analysing samples, and the elimination of sample preparation makes it a technique well suited to an abattoir environment, where direct sampling on carcasses is desirable.

The future of REIMS analysis is likely to focus further on meat quality attributes, continuing the work already underway to assess whether part or all of the lipid profile of a product can be used as a predictor of meat flavour attributes. The intention would be that consumer relevant eating quality data may be displayed on product labelling as a way to boost consumer satisfaction with the meat industry and to reduce food wastage.

Flavour and consumers – an international approach

The flavour of beef is important for consumer satisfaction. A review of the importance of 22 attributes (Henchion *et al.*, 2017), reported that flavour was the most important of the sensory attributes while others (Oliver *et al.*, 2006; Felderhoff *et al.*, 2020) have found that flavour is as important or more important than tenderness for overall acceptability. For this reason, Linda Farmer and colleagues in Australia, USA and Poland have been conducting research to determine how flavour may be understood and managed. Due to their low concentrations, many of the compounds causing flavour are very difficult to analyse. Therefore, a method has been developed to follow "marker compounds", which have been shown to be related to flavour liking but may not be causative (Farmer *et al.*, 2012).

Figure 3. Schematic diagram showing the causes of and mechanisms involved in meat flavour formation.



Studies conducted to date have shown relationships between volatile flavour compounds and ageing, USDA grade, animal diet, fat content, muscle, packaging and cooking method (e.g., Legako *et al.*, 2015, 2016). For example, a comparison of the volatiles from striploin when casseroled, roasted or grilled shows large differences in the balance of volatile compounds, with grilled beef highest in Strecker aldehydes, the roast beef (internal) high in ketones, and casseroled beef high in both ketones and sulphur compounds. These differences are believed to be related to both the temperature and water activity of cooking. Such studies are demonstrating that flavour formation in beef may be understood based on a knowledge of flavour chemistry, sensory perception and meat biochemistry (Figure 3).

The development of common and straightforward analysis methods for beef flavour marker compounds has facilitated international collaboration on this topic. New methods are currently being validated to build on the automatic sampling procedures now available. An understanding how the flavour of beef is affected by different factors will allow us to optimise the flavour potential and consistency of the beef delivered to consumers.

V. INTEGRATED SOLUTIONS – SUSTAINABILITY, INTEGRITY, TRACEABILITY AND EATING QUALITY

Lastly, MP Ellies-Oury presented a study entitled "Combining Animal Performances, nutritional value and sensory quality of meat". This work previously published (Ellies-Oury *et al.*, 2016) aimed to design a new methodological approach to combine together animal performances, nutritional value, sensory quality of meat. A total of 97 variables were recorded from seventy-one young bulls from three breeds (Limousin, Blond d'Aquitaine and Angus). Variables of each group (animal performances, nutritional value, sensory quality of meat) were arranged into either 5 homogeneous Intermediate Scores (IS) via a clustering of variables within each group of variables. In parallel, two Global Indices (GI) were obtained by Principal Component Analysis (PCA) within each group as well. These 3 pools of 5 IS (or 2 GI) were analysed together by PCA to established the links existing among animal performances, nutritional value and sensory quality of meat. Classification based on IS showed no opposition between animal performances and nutritional value of meat, suggesting it is possible to identify animals with a high butcher value and intramuscular fat relatively rich in polyunsaturated fatty acids. Alternatively, with GI, the classification indicated that animal performances were negatively correlated with sensory quality. In conclusion, this method appeared to be a useful contribution to the management of animal breeding for an optimal trade-off between the three groups of variables (animal performances, nutritional value, sensory quality of meat).

CONCLUSION

This paper described recent progress in standards related to beef. For example, the fast-evolving work on eating quality initiated in 2014 has led to the first training sessions for Chiller Assessors this year in Europe (Wales and France). Ian King also explained that the UNECE held regular training sessions, technical meetings and symposia on emerging issues.

He also provided an update on the use of the standards by countries in the UNECE region and beyond and stressed the role of the standards and the included cut descriptions in the international trade and control of meat traded worldwide.

In order to broaden the overview of countries using UNECE standards for meat, countries were invited to report to the secretariat on their use of the UNECE cut descriptions.

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