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# Travaux de recherche internationaux sur la qualité sensorielle de la viande ovine et bovine

## Compte-rendu de discussions à l'occasion du workshop de la Commission Economique des Nations Unies pour l'Europe sur la qualité sensorielle de la viande ovine et bovine

**Mots-clés :** Viande bovine, Viande ovine, Qualité sensorielle

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**Certains participants du workshop de la Commission Economique des Nations Unies pour l'Europe (CEE-ONU) de 6 pays ont approuvé la création de la "International Meat Research 3G Foundation" établie en juin 2017. Ils proposent de discuter de la possibilité d'inclure les principes et les protocoles du « Meat Standards Australia » (qui est un modèle de prédiction de la qualité sensorielle de la viande bovine) dans les normes de la CEE-ONU.**

**Résumé :**
Le Teagasc (institut irlandais de recherche-développement en agriculture) a organisé un workshop de la Commission Economique des Nations Unies pour l'Europe (CEE-ONU) sur la qualité sensorielle de la viande et la classification des carcasses ovines et bovines pour une meilleure satisfaction des consommateurs et la diffusion des normes de la CEE-ONU. Ce workshop a également été soutenu par le "Meat Livestock Australia" (MLA). Avant le workshop, des scientifiques de six pays ont décidé d'utiliser les protocoles du système MSA ("Meat Standards Australia") afin de construire une base de données internationale dans le cadre d'une association à but non lucratif créée pour cet objectif. Le MLA a proposé de faciliter ce projet afin d'assurer l'interopérabilité des données. Ainsi, une fondation nommée "International Meat Research 3G Foundation" a été établie le 12 juin 2017. Son objectif est non seulement d'héberger la base de données, mais aussi de promouvoir au niveau mondial les protocoles du système MSA de classement des carcasses et d'évaluation sensorielle de la viande.

**Abstract: International research on beef and lamb eating quality**
Teagasc (Irish R&D institute in agriculture) hosted a United Nations Economic Commission for Europe (UNECE) workshop focusing on eating quality, beef and lamb carcass grading to underpin consumer satisfaction and the implementation of UNECE standards. The workshop was also supported by Meat Livestock Australia (MLA). Prior to the workshop, scientists from six countries had decided to use MSA consumer testing protocols to develop a global DATAbank under the auspices of a Not for Profit Foundation established for this particular purpose. MLA offered to facilitate a data development project to ensure data compatibility. Consequently, a Foundation under the name, "International Meat Research 3G Foundation" had been established on June 12, 2017. The purpose of this foundation, in addition to hosting the data bank, is to add MSA (Meat Standard Australia) grading inputs and MSA consumer testing protocols to the research in eating quality worldwide.

## INTRODUCTION

A workshop was organized by the United Nations Economic Commission for Europe (UNECE) together with Teagasc and supported by Meat Livestock Australia.

The role of UNECE is to develop standards for international meat trade. UNECE (an inter-governmental organization) was created in 1949 and so was the predecessor of today's Working Party on AgriculturalQuality Standards which aimed at harmonizing national standards into international standards and providing a mechanism for their practical use and implementation.

Among the most important areas for future research is eating quality of meat (Pethick *et al.*, 2011). Jerzy Wierzbicki, Chair of the UNECE Specialized Section's Scientific Reference Group on Eating Quality, reviewed how eating quality became part of the Specialized Section's work and how it has evolved during the past year. He highlighted the 2017 meeting in Milan (Italy) of the UNECE scientific reference group as well as other researchers (Farmer *et al.*, 2016, 2017). These researchers agreed to develop a global DATAbank under the auspices of a Not for Profit Foundation which was established on 12 June 2017 under the name, "International Meat Research 3G Foundation". He noted that the registration process was under way and that the research foundation had no direct links with UNECE.

The aim of this manuscript is to present the global eating quality databank and to outline presentations on beef and lamb eating quality at the UNECE workshop.

## I. THE GLOBAL EATING QUALITY DATABANK

Peter McGilchrist (University of New England, Australia) argued in favour of the value of a national database for evaluating eating quality and compliance.

In the past 7 years there have been more than 19 million carcasses graded by Meat Standards Australia (MSA) at 42 accredited beef processing plants across Australia. For each carcass there are more than 20 individual pieces of data recorded regarding management, property and processor factors plus carcass traits. From this data, the eating quality of 39 muscles in the carcass is predicted for up to 6 different cooking methods. Hence over a 7 year period, there is over 2.6 billion data points recorded in the MSA data base which is managed by the producer owned company, Meat and Livestock Australia.

This data can be downloaded by individual producers, processors (password protected) and researchers (with Industry approval) to gain powerful insights into many aspects of beef production, meat quality, producer performance and the interactions between all sectors of the supply-chain and the environment.

The two major areas for which MSA data has been used to date are to 1.) identifying the incidence and causes of non-compliance for carcass ultimate pH (pHu) and meat colour and 2.) evaluating the eating quality of beef produced across Australia using the MSA Index. These two analyses use information from the MSA data base only, however the opportunities could be far broader such as to combine the MSA grading data with genomic information, environmental records and/or production data to help identify much broader factors impacting meat quality and pHu compliance.

For pHu and meat colour compliance analyses, the MSA data base is ideal because the dependent variable of such analyses is the proportion of a consigned slaughter group from a farm (lot) with high pHu or dark meat colour per lot of cattle. Hence any analyses of this type needs thousands of lots which the MSA data base offers. There have been a few papers published using MSA data (McGilchrist *et al.* 2012, McGilchrist *et al.* 2014) which have highlighted the impact of phenotypes and seasonality on pHu and meat colour compliance. McGilchrist *et al.* (2014) provided insight into seasons/periods when dark cutting was elevated, helping to direct more controlled research to find the causes of non-compliance in those periods and regions of interest. Likewise the phenotypic analysis gave the Australian beef industry strategies for how to minimise dark cutting by increasing animal musculature and reducing physiological age at slaughter (McGilchrist *et al.* 2012).

Meat Standards Australia data can also be used to benchmark and analyse the eating quality of beef produced nationally. For many years beef producers were presented with the raw data for all carcass attributes but producers found it difficult to understand the final effect on overall carcass quality. Recently the MSA index was created which is a single number to indicate the overall quality of a carcass. The MSA index is a weighted average of eating quality scores for 39 different cuts across the carcass cooked using their most common method, aged for 5 days and achilles hung. The MSA index provides a standard measure over time of carcass eating quality plus it is a sound basis for evaluation of the impact on-farm genetic progress and management strategies between seasons and years on eating quality. The MSA index, available to all processors, producers and researchers through the MSA data base also provides the data for a solid benchmarking tool for suppliers of feeder and slaughter cattle. Producers can also analyse all historic data and understand how they can improve eating quality to increase their proportion of cattle hitting the premium areas of carcass payment grids.

In conclusion, when the MSA data base was initiated in the late 90's, the opportunities it would afford the Australian beef industry and insights it would provide were unknown. However due to technological improvements in data storage, data transmission and computational power, the analysis of billions of data points from the MSA data base represents an ever evolving opportunity for producers, processors and researchers.

Dr Rod Polkinghorne, who is one of its initiators, described the Global Eating Quality DataBANK.

There has been widespread scientific interest over many years in consumer focussed eating quality research with the Meat Standards Australia (MSA) program a focus for multiple collaborative projects and discussion. This has brought an appreciation that collection of sufficient data is an expensive exercise and further that any individual country or company lacks a complete range of potential animal, environmental and processing combinations, which restricts the ability to transfer eating quality estimates to other consumer or animal populations.

To address these challenges a number of people and groups that have been actively involved have investigated

mechanisms for formal collaboration and voluntary sharing of data for mutual industry benefit. These discussions have been progressed through the UNECE structure for several years consistent with the ambition to develop and house global standards under a neutral and assessable structure.

A special working group with Poland as a lead rapporteur was convened to address issues of language and data management reporting back to the UNECE Specialized Section on Meat. It has been agreed in principal that the UNECE Bovine Language incorporate additional standards to facilitate standardised description of traits of potential use in beef grading systems and to addend agreed consumer testing protocols. Recommendations will be formally considered at the November 2017 UNECE meeting in Geneva.

It was also recognised that a suitable neutral organisational structure is required to coordinate data collection and facilitate collaborative research work and industry application. It was agreed that a Not For Profit Foundation was appropriate and the International Meat Research 3G Foundation is being registered in Poland to provide this structure. Any group with an interest and involved in consumer based research data collection is invited to join the Foundation and assist in developing the structure and mechanisms required.

The working group considered alternative models for data collection and pooling, the principal options being a multitude of individual databases and standard protocols for pooling or exchanging common format data versus a single central structure holding individual datasets for multiple owners. The central structure was judged to have significant advantages in cost and long term maintenance providing individual data security could be guaranteed.

The following objectives and mechanisms were agreed to start the project.

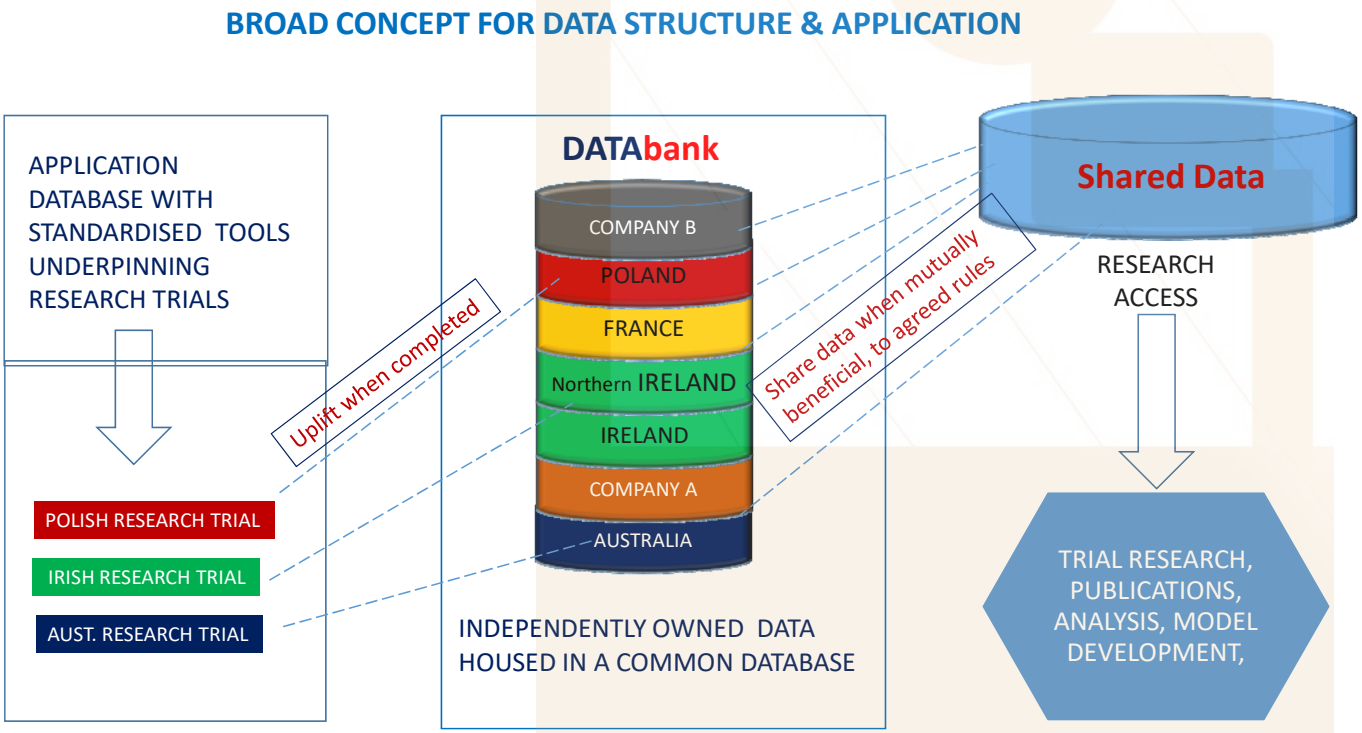
STAGE 1:Develop a global eating quality 'DATAbank', with cloud hosting, along with web-based research 'tools' for individual country trials to underpin data standardisation within each countries 'DATAbank account'.

STAGE 2:Develop and agree the protocols for how data may be shared. Once agreed, data to be shared to be uplifted to a Research database for agreed joint analysis.

STAGE 3:Develop a funding model for self-sufficiency.

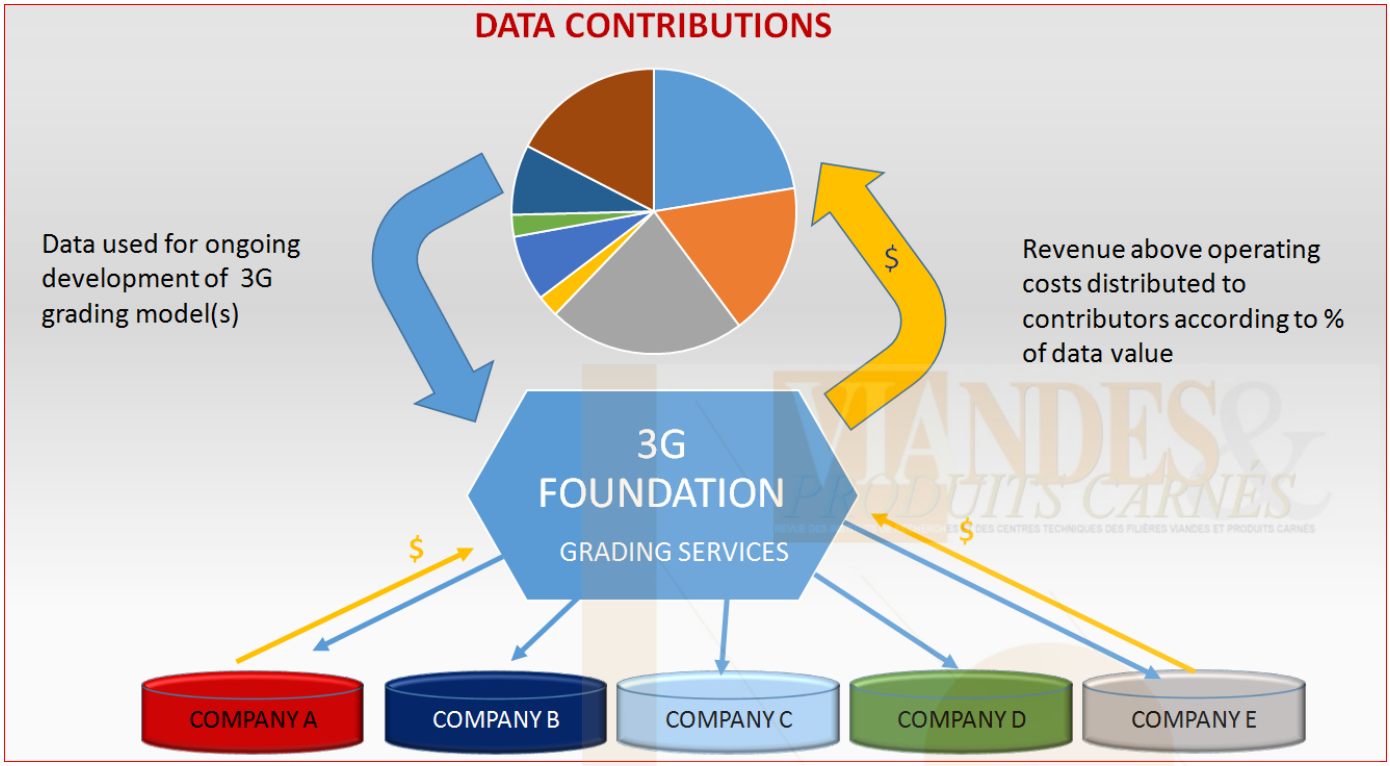
Key principles agreed include each country or organisation that stores data in the DATAbank retaining full ownership and control of which data with would be shared, with who, for what agreed purpose and under what conditions. The proposed structure is represented in the following illustration (Figure 1).

**Figure 1: Proposed structure of the DATAbank**




The Foundation is planned to operate in a similar fashion to ICAR (International Committee of Animal Recording) with a management board representing the leaders of scientific working groups that provide technical input and recommendations. While the initial activity is centred on research and scientific collaboration it was recognised that it may lead to commercial application over time with potential issues in regard to equitable arrangements for parties who had made differing levels of contribution. A principle was agreed, represented in the diagram below (Figure 2), that revenue generated above the cost of management would be returned to members in proportion to their data contribution as a fee for use of the data with the proportions adjusted continually to recognise the current data mix.

**Figure 2:** **Business model of the DATAbank**




Then, Rod Polkinghorne (Polkinghornes Australia) discussed the potential for a collaborative Eating Quality Prediction Model for beef grading.

As all beef industry revenue comes from the ultimate consumer it is critical that any form of beef grading system reflect value to the consumer. Despite this appearing obvious it has not been the case with conventional systems which conventionally describe product in terms of breed, origin, cut and raising claims all of which lack any precision in regard to the final eating quality experience of the cooked meal. Typically the consumer is faced with a complex set of largely irrelevant information and asked to interpret this to make their own prediction of a result. Consumers do not buy cattle or carcasses. They do buy cuts but a cut name describes anatomy rather than a result with a huge potential quality range within any cut.

What is needed is a reversal of information flow where the consumer is provided with a clear, simple and accurate individual retail pack description that guarantees an end meal result when a defined cooking method is utilised. Other contemporary consumer products are simple to buy, the result is clear and there is no expectation that the consumer should interpret underlying science: consider an airline ticket or fuel purchase.

With the meat science knowledge, we now have it is possible to deliver a clear, simple and reliable description of an end meal result. The illustration below displays a concept of how a retail concept could be delivered; decide on a meal type, consider the occasion and the selection is delivered by a three brand/quality strategy (Figure 3).

**Figure 3:** **Practical use of the eating quality model which underpins beef brands**

| The Occasion |  Grill |  Roast |  Slow Cook |  Stir Fry |  Shabu Shabu |  Yakinku |
|---|---|---|---|---|---|---|
| Very Special | Brand A++ | Brand A++ | Brand A++ | Brand A++ | Brand A++ | Brand A++ |
| Special | Brand A+ | Brand A+ | Brand A+ | Brand A+ | Brand A+ | Brand A+ |
| Good Everyday | Brand A | Brand A | Brand A | Brand A | Brand A | Brand A |

Given sufficient data this promise can be delivered now. Meat Standards Australia (MSA) research and market results demonstrate that consistent quality levels can be predicted and delivered, although the simplicity of the illustration is rarely delivered with a mix of old description and brand promotion. MSA experience also demonstrates that improved returns are delivered across the supply chain when product performance is improved through reduced variation and clear description.

Consumer prediction modelling is a powerful and effective tool that could revolutionise beef marketing and industry performance through consistent guaranteed quality choices and simple description delivering improved consumer value. To be effective, however, large volumes of data are required; firstly to define consumer sensory response in order to understand the grading target and secondly on which to develop effective prediction.

A number of research and private industry groups have been collaborating and utilising common protocols for up to 20 years with data held in multiple countries now encompassing responses from over 150,000 consumers. Currently these data are held in isolation and have been used to develop country or company specific prediction models. Each model has deficiencies arising from the restricted product tested or the volume of testing and all would be stronger if data were pooled.

The opportunity for data pooling and mutual development of linked models within a global structure is exciting as it can provide a far better analysis of the multitude combinations of genotype and environment found in different countries and regions. A cooperative approach can reduce the total research cost while delivering a superior global outcome through the linkage of data from a diverse animal, environmental and processing range. In a global trading world it can also provide an ability to match consumers and product in any location.

We have the potential to describe an individual beef meal result for any consumer population, from any muscle, cooked any way from any carcass from any source! That has to be worth the effort.

## II. COLLABORATION AROUND THE MSA SENSORY TESTING PROTOCOL

Dr R.D. Warner and collaborators (R. Polkinghorne, P. McGilchrist, J. Galletly, L. Huynh, S. Bonney, K. Kobayashi, D. Frank, H. Ashman, M. Ha) presented their work entitled "Effect of dry ageing on consumer sensory scores and flavor chemistry of beef longissimus"

Dry aged beef is being marketed as a premium product and is used in a small number of upscale restaurants and retailers in Australia and around the world. Previously, sensory panels conducted in the USA failed to show the superiority of dry aged meat. Comparing dry and wet aged beef, they showed that there was no difference in tenderness and flavour scores between wet and dry aged beef products. In contrast, a study from New Zealand showed better flavour and overall liking for three week aged beef longissimus. This project examined the effect of dry ageing on eating qualities and yield of Australian beef loins in comparison to wet ageing. Also, consumer trends and perceptions of dry aged meat were investigated.

Although dry aged beef currently constitutes less than 10% of overall beef consumption, market analysis showed a substantial value of the dry aged meat market (US$10.4 billion) in 2015 and this value is expected to reach US$11.2 billion by 2020. Significant market movement is occurring in USA, Europe, Asia and the Middle East, with substantial investments from Germany and USA set to become large exporters. Key target consumer groups for dry aged beef include those conscious of health and sustainability, and meat lovers, selective foodies and premium players.

Initiated by Meat and Livestock Australia and Top Cut Foods Pty. Ltd., Australian beef longissimus (striploins and cuberolls; n=48 of each, from 24 beef carcasses) were dry or wet aged for five or eight weeks. Using established Meat Standard Australia protocols, sensory evaluation was conducted with untrained consumers. The results showed that dry aged beef longissimus was scored higher than the wet aged counterparts, both at five and eight weeks, for all four attributes tenderness, juiciness, flavour and overall like. The highest sensory scores for all four attributes and MQ4 scores were observed for dry aged products at five weeks. Flavour chemical analysis of dry and wet aged samples at five-week ageing (n=12 of each treatment) with GC-O and headspace SPME-GC-MS showed differences in flavour and aroma volatile profiles between dry and wet aged samples. Odour intensity for a number of peaks including 2-methylproponal/acetone, 2-ethyl-3,5-dimethylpyrazine, 3-ethyl-2,5-dimethylpyrazine, (E)-2-nonenal and 1-octanol were higher in the dry aged samples. The main grilled beef odour impact volatiles corresponded with heat generated pyrazine compounds, well-known components of grilled beef aroma and of the Maillard reaction. In addition, dry aged beef had substantially higher concentrations of 3-hydroxy-2-butanone, acetone, pyrazines and hexanal whereas ethanol and acetic acid were much higher in wet aged beef. The dry aged samples had higher pH than wet aged samples at both five and eight weeks. This pH difference may have contributed to differences in volatile profiles due to pH-dependent Maillard reactions during cooking. Weight loss during ageing was higher in dry aged products. No significant difference in total water content between dry and wet aged products was found and dry aged beef had higher lipid oxidation (measured by TBARS), relative to wet aged product, only at eight weeks. In conclusion, consumers preferred the tenderness, juiciness, flavour and overall liking of beef longissimus dry aged for 5 or 8 weeks, relative to beef *longissimus* wet aged for the same period. Flavour chemical analysis suggests that the higher acceptability of dry aged beef products may be due to higher levels of pyrazines (generated in the Maillard reaction during cooking) and lower levels of unacceptable flavour compounds.

Dr Garth Tarr, (Sydney University, Australia) answered to the following question "Are consumers willing to pay for eating quality?"

The notion that consumers are willing to pay for a premium for eating quality is a key assumption underpinning global research into meat eating quality. Consumer data on willingness to pay (WTP) has been collected in all Meat Standards Australia (MSA) consumer taste panel experiments since 2008.

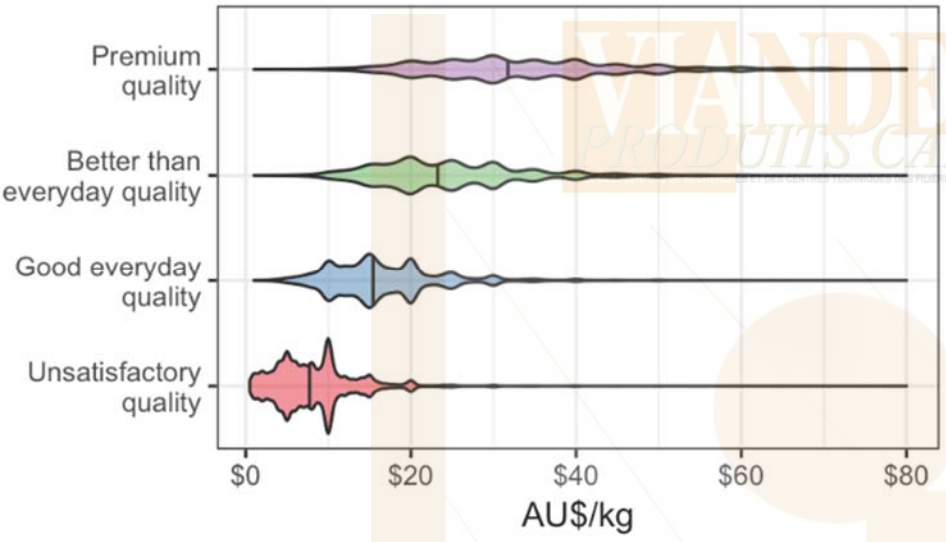
The WTP question is presented after seven sensory samples have been evaluated to avoid price influencing sensory response. Results are recorded in Australian dollars per kg on line scales for each category choice (unsatisfactory,

good everyday, better than everyday and premium) with the scale ranging from A$0 to A$80 per kg.

Consumers are asked: "Based on the beef you have just consumed, please mark the line at the price per kg you believe best reflects the value for each category". It is important to note that the question asks about a "value" price, not the maximum price that they would be willing to pay. The question also refers to beef that they would assign to each category rather than to actual samples presented as consumers may not accurately recall the second sample, for example.

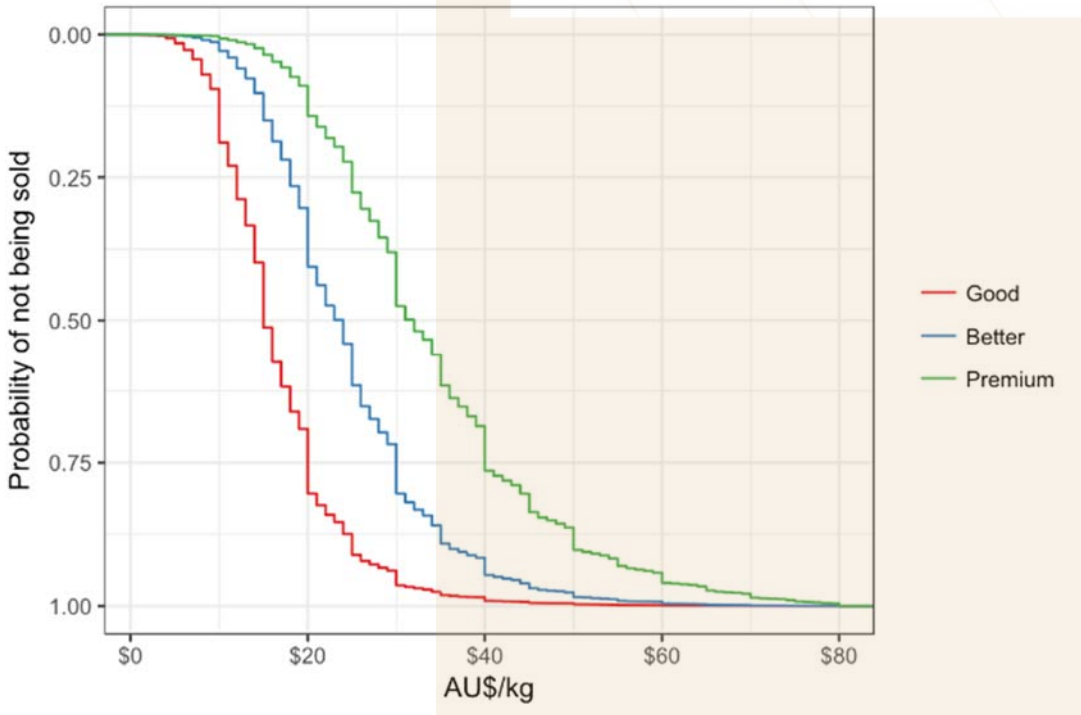
Over the past 10 years, 36,167 Australians across a broad range of demographic profiles have participated in consumer taste panels and recorded their willingness to pay at the conclusion of the experiment. Figure 4 shows the raw prices across the 10 years of data that consumers said they would be willing to pay at each grade. The median price for unsatisfactory is $8/kg; $15/kg for good everyday quality; $24/kg for better than everyday quality; and $32/kg for premium quality.

**Figure 4: violin plots of willingness to pay for 36,167 Australian consumers from 2008 to 2017**




An alternative method to visualise the prices consumers are willing to pay is given in Figure 5. An empirical distribution function has been flipped vertically so that it behaves analogously to a demand curve where demand (or willingness to buy) decreases as price increases. The gradient of the curve reflects consumer price sensitivity. The steeper the curve, the more sensitive consumers are to changes in price. In Figure 5, apart from the clear shift in willingness to pay between grades, there is also a change in the gradient of the curves, where consumers are less price sensitive for premium quality and more price sensitive for the good everyday quality product.

**Figure 5: Empirical distribution function for Australian consumers flipped on the y-axis so that it can be interpreted similarly to a classical demand function**

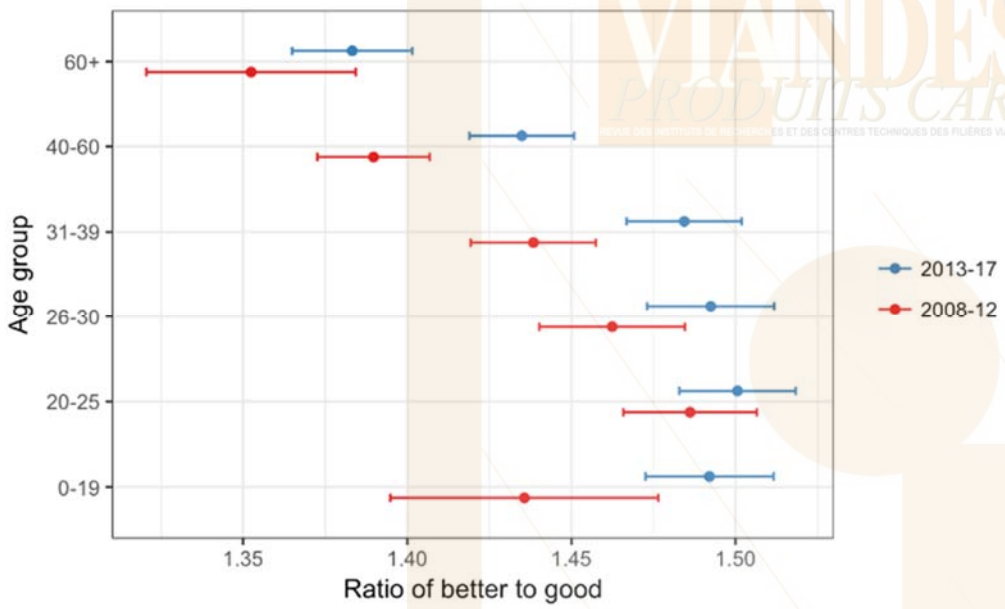


Ratios are typically used to model willingness to pay. For example, the ratio of WTP for "better than everyday quality" relative to WTP for "good everyday quality" (ratio of better to good). A ratio approach facilitates comparisons over time (eliminates any inflation effect) and across countries (independent of currency). It also overcomes the critique that consumers may not know realistic $/kg figures, even though they do know what sort of markup they would be willing to pay for higher quality product.

As has been found in previous studies (Lyford *et al.,* 2010; Bonny *et al.,* 2017) consumer demographics have only a marginal influence on willingness to pay, with the exception of consumer age.

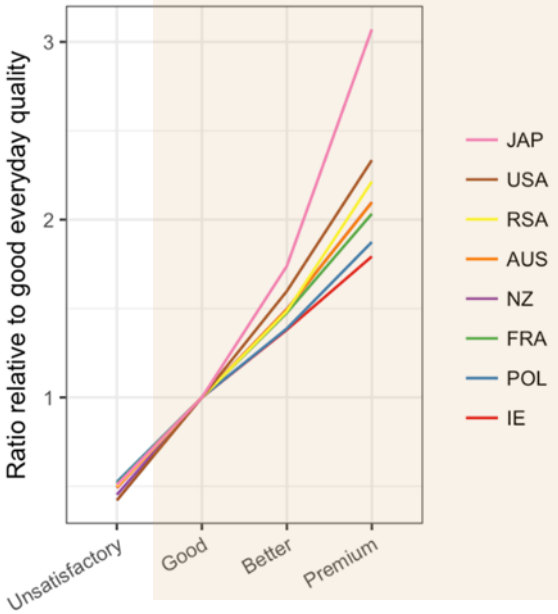
Our analysis suggests that there has been a change in the willingness to pay across age brackets over the past 10 years. Figure 6 shows that Australian consumers in older age brackets are now willing to pay a higher premium for quality. This is perhaps attributable to "stickiness" of WTP over time, the WTP of people in the earlier 5 year bracket is similar to the WTP of the next age group up in the next time period.

**Figure 6: predicted means for the ratio of better than everyday quality to good everyday quality by age group and time period for Australian consumers with 95% prediction intervals**




Finally, an international comparison of MSA-like trials compared consumers from New Zealand (3360 consumers), Poland (900), USA (12,780), Japan (2280), France (1500), Ireland (1380) and South Africa (720). We find remarkable consistency between countries in the discount they apply for unacceptable quality relative to good everyday quality (roughly half the price). Figure 7 also shows that consumers in various countries are willing to pay around 50% more for better than everyday quality than good everyday quality and around twice as much for premium quality product relative to good everyday quality.

**Figure 7: average willingness to pay ratio relative to good everyday quality product across consumers from Japan, USA, South Africa, Australia, New Zealand, France, Poland and Ireland**



There are some differences between countries. Japanese consumers place a greater premium on high quality product. Irish and Polish consumers are the most price sensitive for premium product. However, there is a trend across countries: consumers are willing to pay a substantial premium for higher quality beef.

Dr David Pethick and his colleagues (L. Pannier and T. Pleasants, Murdoch University Australia) gave a presentation entitled "Towards a continuous grading model for MSA for lamb".

The current MSA for lamb is a best practice pathway approach to underpinning the eating quality of lamb cuts. The work underpinning the current MSA lamb was published as a series of scientific papers in 2005 (Special edition 1) and is still entirely valid. The major implications of the current system are best practice processing underpinned by manipulating the pH decline of the muscle in the carcase post slaughter (electrical stimulation) combined with aging requirements of the meat matched to the rate of pH decline. In addition, a key component is the need for registered producers ensuring that lamb producers understand the principals of supplying lamb to underpin the consumer.

Subsequent work undertaken as part of the Cooporative Research Centre for Sheep Industry Innovation including the initiation of the Information Nucleus genetic resource flock has lead to a raft of new information in relation to the science of lamb meat quality (Special editions 2,3 and 4; 2006, 2007, 2014). This work has lead to the realisation that an individual grading system is possible to underpin a more refined and accurate prediction of consumer satisfaction of cooked lamb. The new aspects include:

- positive effect that intramuscular fat plays in determining the eating quality of lamb
- the –ve effect that muscling (or lean meat yield) plays in determining the eating quality of lamb
- the strong influence of sire genetics on the eating quality outcome
- continued selection for lean meat yield in the Terminal sire seed stock sector will decrease the eating quality of lamb

The basis for underpinning carcase grading as an additional input into MSA cuts based lamb grading comes from MSA sensory consumer testing of the grilled short loin and topside steaks from 1,422 Terminal and Maternal sire cross and 221 Merino lambs. In total this equals 3,286 cuts of lamb tested by 5,476 consumers. A small number of Dorper x Merino cross lambs were also tested but the data was insufficient to make grading predictions at this stage. All lambs were slaughtered to current MSA specifications including electrical stimulation of the carcase and 5 days aging of the meat.

**Table 1: Descriptive statistics of lambs sired by Terminal and Maternal sires used in consumer sensory studies**

| Variable | N | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| HCWT (kg) | 1422 | 24.0 | 3.8 | 15 | 40.0 |
| IMF% | 1422 | 4.6 | 1.1 | 2.0 | 9.8 |
| LMY% | 1216 | 57.7 | 3.3 | 45.3 | 66.3 |
| GR tissue depth (mm) | 1422 | 15.5 | 6.0 | 2.0 | 30.0 |

HCW = hot carcase weight; IMF = intramuscular fat; LMY = predicted CT lean meat yield

The consumer testing was based on the standard MSA sensory protocols with untrained consumers consuming grilled lamb steaks cooked to medium. Each consumer rated the steaks on a scale from 0 - 100 for tenderness, juiciness, liking of flavour and over liking. They also ticked one box as their final grade answer, namely unsatisfactory (2*), good every day (3*), better than everyday (4*) or premium (5*). The distribution of grades is shown in Table 2 for the short loin and topside respectively.

**Table 2: The average frequency of sensory grades for the grilled short loin and topsides steaks across the lamb progeny of all sire types**

| Cut | Star 2 | Star 3 | Star 4 | Star 5 |
|---|---|---|---|---|
| Loin | 7 | 34 | 35 | 24 |
| Topside | 31 | 51 | 14 | 4 |

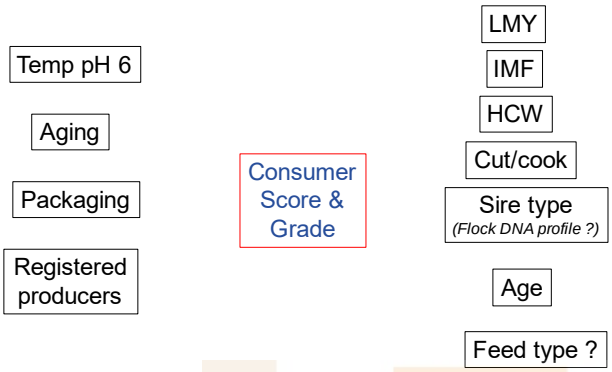
The best predictor of the final grade or star rating was:
Lamb MQ4 score = 0.3 (T) + 0.1 (J) + 0.3 (F) + 0.3 (OL)

The statistically significant predictors of the MQ4 score were (i) sire type (Merino, Maternal, Terminal) (ii) an accurate estimate of CT based lean meat yield [such as with the new DEXA based systems discussed by Gardner) and (iii) intramuscular fat.

A final new MSA lamb model for predicting the eating quality of lamb cuts can be designed.

The elements of a final MSA prediction currently being investigated are shown in Figure 8. An area of intense investigation in Australia is the development of on line technologies for grading of lean meat yield and intramuscular fat in lamb carcases.

**Figure 8: The elements of a new Meat Standards Australia lamb model currently being evaluated**




Andrea Garmyn (Texas Tech. University, USA) presented the New Zealand experience regarding beef and lamb grading for satisfying the consumer.

Beef in New Zealand is classified into carcass categories based on carcass type (sex) and further sorted based on fat thickness, carcass weight, and muscling (NZMCA, 2004a). This classification system is used for marketing purposes, but provides no indication of eating quality. In 2013, Silver Fern Farms, a leading red meat producer, launched a consumer-based grading system that relies on the chiller assessment of marbling, ossification, pH, ribfat thickness, and carcass weight to predict eating quality on an individual cut by cooking method basis and incorporates chiller assessment of meat and fat color for aesthetic purposes.

In order to develop the model used for this grading system, carcasses were selected with a wide range of marbling and ossification scores to generate the model algorithm. This was achieved via three sample collections (August, November, April) at three chilled beef abattoirs (Pacific, Belfast, Finegand) to account for seasonal and regional variation that may exist in the beef population. Each sample collection focused on a strategic concentration to build a robust model. Initially, carcasses were selected to evaluate the interaction between cut (32 different muscles) and cook method (grill, roast, slow cook, stir fry) in short aged beef, as well as to examine grills *vs.* roasts within one cut, and to assess consumer responses in New Zealand *vs*. United States. The second and third collections focused on the effects of *postmortem* aging and alternative carcass suspension methods. Ultimately, 276 sides were utilized to generate 96,600 consumer samples, which were tested by 13,800 consumers in New Zealand and the United States. This grading system now allows for the selection of premium carcasses with guaranteed eating quality. In 2013, Silver Fern Farms Premier Selection Reserve Beef value-add restaurant product range was released to market following consumer and customer testing. Their value-add retail beef range was released in 2014 with an EQ Master Grade guarantee. By 2016, over 1 million retail packs had been sold. Silver Fern Farms retail packs are also available in select international markets.

Much like beef, lamb in New Zealand is classified into carcass categories according to maturity of the carcass, sex, fat content, weight, and muscling (NZMCA, 2004b). Again, this classification system is used for marketing purposes, but offers no insight into eating quality. Based on the success of Silver Fern Farms Reserve premium beef program, the company sought out to determine which traits could be used on farm or in the abattoir to predict lamb eating quality. Gender, weight, GR score, and pH were used as carcass selection parameters. Four muscles (loin, rump, topside, and knuckle) were retained from those carcasses and aged 1, 7, 14, or 28 days *postmortem*. Weight gain, breed, and diet were also available during selection. Carcasses were selected at two time periods (February, April) at two different abattoirs (Takapau, Finegand) each time to account for seasonal and regional variation that may exist in the lamb population. Ultimately, 385 carcasses were utilized, which were tested by 3,240 consumers in New Zealand and the United States. To ensure a premium lamb product, carcass weight, sex, and GR should be considered. Incorporating season, feed type and breed type can improve the sorting accuracy. Ultimately, this system can predict eating quality of the 4 tested cuts, when grilled, following postmortem aging anywhere from 1-28 days; however, logistical limitations have hindered implementation at this time.

Finally, Prof. John Thompson (UNE) and his collaborators (RJ Polkinghorne, J Philpott, J Pervovic, J Lau, L. Davies, W. Mudannayake, D. Summerville, J. Nixon, R. Watson, G. Tarr) gave a presentation entitled “Packaging effects on eating quality”.

The Meat Standards Australia (MSA) beef grading model uses commercial inputs to predict eating quality of individual cuts prepared using different cooking methods. The MSA grading model is dynamic and capable of including new inputs if shown to impact on eating quality. An example of the dynamic nature of the MSA grading model was the addition of hormonal growth promotants (HGP) as an input, after research showed that HGPs had a large negative effect on eating quality of some muscles in the carcass. The scientific literature makes reference to a negative effect on beef eating quality when retail cuts are packaged in high oxygen gas packs, although generally the magnitude of the effect is not well quantified. If the effect of high oxygen packaging can be quantified it could be included as an input into the MSA beef grading model.

Previously the MSA grading system excluded both high MCS (MCS) at grading (ie MCS > 3), and also high ultimate pH carcasses (pHu > 5.7) as threshold traits. There are questions as to the usefulness of MCS at grading as a predictor of eating quality. Recent studies have also shown an increasing incidence of grass fed carcasses with high MCS and low ultimate pH at grading (JM Thompson and R Polkinghorne, unpublished data). If the high MCS and low ultimate pHu carcasses at grading are regraded at a later time the proportion of carcasses that have high MCS is reduced. This questions the usefulness of MCS at grading as a tool to exclude carcasses from the MSA beef grading system.

This experiment examined the effect of three different packaging methods (ie MAP – cuts packed in 80% oxygen;20% CO2, OWP - cuts wrapped in oxygen permeable

film, or VSP - vacuum packed cuts in bags or preformed pouches) across a matrix of MCS at grading (1C, 2, 3, 4 and 5 MCS), with high or low ultimate pH (pH> or < 5.7) and a range of dentition categories (0, 2, 4 and 6 tooth carcasses).

The 48 beef carcasses used in this experiment were selected largely from grass fed carcasses slaughtered at one abattoir over a single day. The striploin, rump and tenderloin primals were collected from both sides at boning, vacuum packed and allocated to either 5, 12 or 40 days ageing treatments. After ageing primals for the appropriate time they were broken out of the vacuum packs and the mm. *longissimis dorsi, gluteus medius* and *psoas major* prepared as steaks in the three packaging treatments.

The consumer acceptability of meat colour in the retail packs was scored using untrained consumers. OWP packs were scored one day after packaging, whilst the MAP and VSP packs were scored at three, five and seven days after packaging. Consumer appreciation of meat colour of the retail packs was scored using a line scale anchored by the words extremely unappealing/extremely appealing. In addition consumers were also asked to tick one of three boxes, the first indicated they would definitely buy the retail pack, secondly they would definitely buy the retail pack if discounted, or thirdly they would definitely not buy the retail pack. After nine days steaks from the retail packs were frozen and allocated for sensory testing. Steaks were thawed and grilled steaks tested using untrained consumers for tenderness, juiciness, like flavour overall acceptability and a composite meat quality score (MQ4) using the MSA consumer protocol.

Results and discussion: Results showed that MCS at grading, ultimate pH class and dentition category did not impact on consumer sensory scores ($P>0.05$). Packaging had a large effect on consumer sensory scores with steaks stored in high oxygen MAP packs scoring 10 to 12 lower scores (on a 100 point scale) compared with steaks packed in either OWP or VSP systems ($P<0.001$). The MAP penalty was similar regardless of muscle, or the time primals were aged in the vacuum pack. This suggested that the MAP effect was not caused by inhibition of post-mortem proteolysis, but rather oxidative cross linking of proteins.

A discriminant analysis of the consumer appreciation of MCS at retail showed boundaries between definitely would purchase/definitely not purchase unless discounted/definitely not purchase was 62 and 38. This confirmed that consumer appreciation of MCS at retail was related to purchase intent.

Using the data from day one in the OWP packs and day three for the MAP and VSP packs showed that the MAP had the highest consumer appreciation of meat colour followed by the OWP packs, with the VSP packs having the lowest consumer appreciation of meat colour ($P<0.001$).

Within the OWP packs, MCS at grading was not related to consumer appreciation of meat colour at retail after one day in the retail pack. Given that the oxygen film of the OWP packs was permeable to oxygen the expectation was that the surface of the OWP steaks from low MCS carcasses would have bloomed and converted the dark purple deoxymyoglobin to a layer of bright red oxymyoglobin on the cut surface, which would have resulted in higher consumer appreciation of meat colour at retail. However, this did not occur as the current experiment showed no relationship between MCS at grading and consumer appreciation of meat colour in retail packs.

Within both the MAP and VSP packs, MCS at grading were not related to consumer appreciation in meat colour in retail packs when evaluated at three, five and seven days after being placed in the retail pack. Previous studies have shown that high oxygen MAP tended to increase the effective penetration of oxygen in the surface of the meat so that even dark cutting beef appeared to be bright red when packaged in high oxygen MAP. Hence the lack of any relationship between MCS at grading and consumer appreciation of meat colour in MAP was not surprising. Similarly in VSP the deoxymyglobin would remain in the reduced form and remain dark purple in colour, hence the lack of relationship between MCS at grading and consumer appreciation of meat colour in VSP was also not surprising.

In conclusion, the recommendation from this experiment was that MSA include a penalty for high oxygen MAP as part of the MSA model. Obviously, how long after MAP before the effect was apparent, along with the effect of other gas mixtures on the magnitude of the MAP effect still needs to be investigated.

It was also recommended that MCS at grading be removed as an input trait in the MSA beef grading scheme which has now occurred.

## CONCLUSION

The MSA system is based on estimating the eating quality response of untrained consumers, i.e. the population who purchase meat. Australia has already a large data set of consumer responses to beef and lamb. This has allowed the development and commercial application of the MSA prediction tool for beef within Australia.

Data sets using common MSA protocols have now been obtained in several countries (France, South Korea, Poland, Republic of Ireland, New Zealand, Northern Ireland, South Africa, United States of America). It is now proposed to generate an international database joining these national datasets since the MSA model is an adequate tool for predicting the eating quality of beef in all these countries. Indeed, the value of a combined global database is now recognized as well as cooperative development of eating quality standards. In addition, there is a trend across countries that consumers are willing to pay more for higher quality beef.

More recent research has been developed using the MSA protocols and standards to assess eating quality of dry aged beef or following different packaging methods. The MSA grading model is indeed dynamic and can include new inputs important for eating quality such as different packaging methods or longer ageing periods in interaction with existing factors already present in the MSA grading scheme.

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