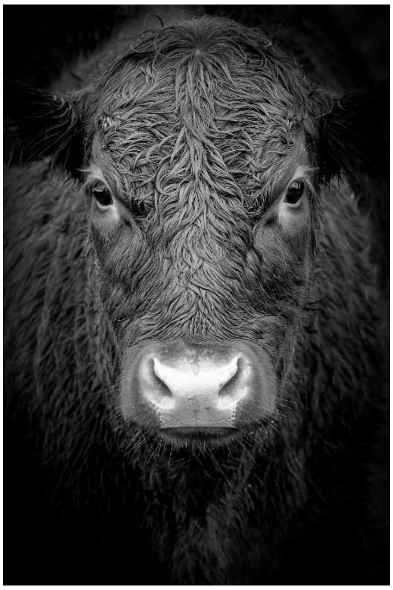
BeefQ
Beef Eating Quality



Final Report

2018-2022

Authored and compiled by:

Phillipa Nicholas-Davies, BeefQ Project Coordinator, Aberystwyth University

Rod Polkinghorne, Alix Neveu & Holly Cuthbertson, Birkenwood Ltd

Wenyang Jia, Lynda Perkins & Nigel Scollan, Queens University Belfast

Project funded by:

Cronfa Amaethyddol Ewrop ar gyfer Datblygu Gwledig: Ewrop yn Buddsoddi mewn Ardaloedd Gwledig

European Agricultural Fund for Rural Development: Europe Investing in Rural Areas

Llywodraeth Cymru
Welsh Government

BeefQ Project Partners:

Beef Processing Companies contributing to the BeefQ Project:

Contents

List of Tables

List of Figures

List of Images

1 Executive Summary

The BeefQ project aimed to improve the long-term financial sustainability of the Welsh Beef supply chain by developing and testing a technology (based on the Australian Meat Standard (MSA) system) that provides a sound scientific basis for demonstrating the eating quality (EQ) of Welsh Beef to consumers. As well as building capacity and confidence in the Welsh Beef sector through the development and testing of this technology, BeefQ aimed to demonstrate how the data collected through this system can be used for improved business decision making and how it can provide opportunities for improved supply chain co-operation and communication. The pre-competitive nature of the BeefQ project also aimed to contribute to the long-term sustainability of Welsh Beef producers and supply chains post Brexit. This report highlights the key activities undertaken in the BeefQ project and includes recommendations as to how eating quality can be moved forward in the UK post the BeefQ project.

The testing and demonstration of the BeefQ eating quality prediction system comprised of four main pieces of work. The first, important for upskilling and a legacy investment, was the inclusion of a meat science course delivered over 10 days in conjunction with practical training in chiller assessment of beef eating quality utilising UNECE protocols. A total of 10 course participants from 5 commercial meat processing plants across Wales and England and BeefQ partner Hybu Cig Cymru (HCC) took part in the training.

The second major piece of work involved a survey of 2090 beef carcasses slaughtered in processing facilities in Wales and England. The purpose of the carcase survey was threefold: to characterise the population of beef being slaughtered through PGI Welsh Beef approved processing plants; to identify a representative sample of cattle for consumer testing and to determine if information currently recorded on the cattle passport and the EUROP classification system could be used as suitable proxies for UNECE EQ grading input data. An extreme range of 69 breeds and crosses were represented in the sample with about 1/5th being from dairy breeds. This underlines the diversity within the cattle population and the challenge faced to utilise breed within potential eating quality estimation procedures. There was also significant variability in eating quality indicators, reinforcing current perceptions of eating quality variability in beef. Whilst there was some correlation between EUROP fatness scores and UNECE rib fat and marbling scores, there was too much variability within the data to use EUROP fatness as a proxy for eating quality variables.

The MSA grading model, used as the basis for eating quality prediction in the BeefQ project, is a dynamic model and modifications and adaptations can be made to the model to ensure accurate prediction of eating quality under different production environments and systems, such as those in Wales. To adapt the model for UK conditions, consumer taste testing (the third major piece of BeefQ work) of a subsample of beef, representative of that observed in the carcase survey, was conducted using the standard protocol developed in Australia for the MSA system (Watson et al, 2008). 1200 consumers took part in 20 taste testing sessions across England and Wales. The samples tasted represented a range of cattle types (sex, age, breed), cuts (striploin, tenderloin, eye round/salmon, feather blade), carcase hang method (Achilles vs tenderstretch) and aging (7 and 21 days). The analysis of the consumer data provided strong evidence that Welsh and English consumers clearly differentiate eating quality into 4 distinct categories from unsatisfactory to premium and that a universal set of sensory weightings and cut off values can adequately define these categories. Data collected at the same time on willingness to pay for beef of differing eating quality indicated that Welsh and English consumers were willing to pay less for poor quality beef but more for premium quality beef than consumers studied in Australia. The value trade-off between eating quality and price was stark providing a strong indication that consistent eating quality would be related to significantly different price points. The consumer tasting data also indicated that individual muscles reacted differently to carcase suspension and aging methods tested, suggesting that a muscle, rather than carcase based approach to post slaughter processes to improve eating quality is appropriate.

One of the outcomes of the industry wide survey on eating quality conducted by BeefQ in 2021 was the lack of clarity regarding how an eating quality system might be implemented and who will take the lead to implement change in the eating quality space. To address some of these concerns, an eating quality grading pilot (the 4th piece of work to test and demonstrate the eating quality prediction system) was implemented at BeefQ project partner Celtica Foods Ltd. This pilot involved the eating quality grading of carcasses and consideration of the costs/practicalities of implementing the grading process.

In addition to the work developing, testing and demonstrating the BeefQ beef eating quality prediction system, significant work has been undertaken to engage industry stakeholders in discussions around beef eating quality and views on the best way forward for the industry. These activities included farm-based events, industry conferences and meetings and Further and Higher Education sessions. A series of videos have also been produced describing the key on farm factors influencing beef eating quality and how these can be influenced, and a step-by-step description of the Celtica pilot. An industry stakeholder survey was undertaken to gauge views on current beef valuation systems in the UK and the benefits and barriers to a system that included eating quality parameters. The main concerns with respect to barriers to implementation related to fear of change across the industry and supply chain issues such as lack of cooperation, fairness of cost/benefit within the supply chain and general lack of leadership to take change forward in the UK beef industry. Benefits highlighted included increased sales, improved value within the supply chain and reduced wastage through producing animals that meet consumers requirements. The majority of those directly involved in the production and processing of beef believed the beef industry needs to evolve from the current EUROP beef valuation system and that there is an industry wide need to introduce a system of assessment and reward for beef eating quality. Views on how such a system should be implemented were more varied, with an extension to the current EUROP grading system being only slightly favoured over a replacement to the EUROP system.

This final report concludes with useful information for those wishing to undertake further beef eating quality prediction for research or commercial purposes. Five recommendations are also made by the BeefQ Project Management Group, and ratified by the BeefQ Stakeholder Group, as key to moving the beef eating quality agenda forward in the UK after the completion of the BeefQ project.

Recommendation 1 - The EQ prediction tools based on the MSA system have been successfully tested and demonstrated in the BeefQ project

Recommendation 2 - Data collected by the BeefQ project to develop the eating quality prediction model will be held in the DATAbank hosted by the International Meat Research 3G Foundation.

Recommendation 3 - Communication and dissemination resources will be hosted by Hybu Cig Cymru (HCC) once the BeefQ project has ended.

Recommendation 4 - Stakeholder feedback indicates that transparent, national, eating quality (EQ) prediction standards are required in order for the industry to move forward.

Recommendation 5 - Further research is needed in the UK to take the beef eating quality agenda forward including how eating quality fits in with the environmental quality agenda; how selecting for efficient animals affects eating quality; identifying potential trade-offs/synergies between eating quality improvement and performance objectives, more pilots and trialling on eating quality prediction, particularly in the context of larger meat processing businesses, and finally development of a set of standards for eating quality prediction in the UK.

2 Introduction

The BeefQ project aimed to improve the long-term financial sustainability of the Welsh Beef supply chain by developing and testing a technology (based on the Australian Meat Standard (MSA) system) that provides a sound scientific basis for demonstrating the eating quality of Welsh Beef to consumers. As well as building capacity and confidence in the Welsh Beef sector through the testing and demonstration of this technology, BeefQ aimed to demonstrate how the data collected through this system can be used for improved business decision making and how it can provide opportunities for improved supply chain co-operation and communication. The pre-competitive nature of the BeefQ project, benefitting the whole industry, also aimed to contribute to the long-term sustainability of Welsh Beef producers and supply chains post Brexit.

The concept for the BeefQ project evolved from the publication of a number of key strategic documents that highlighted the challenges for the Welsh red meat sector and recommendations for overcoming them.

The Review of the Welsh Beef Sector (2014) provided recommendations to improve the sustainability of the sector in Wales and several of these are directly addressed by the BeefQ project, including: a market led approach for delivering consistent high-quality beef, increased coordination and collaboration in the supply chain and the need to review the current EUROP grading system to ensure its fitness for purpose.

The Strategic Action Plan for Red Meat 2015-2020 identified two key strategic priorities: To increase demand for Welsh red meat products (thereby increasing sales and returns) and to improve production efficiency (thereby increasing quality supply) whilst maintaining the environment and landscape of Wales. There were several identified constraints to achieving those goals, however. The first is that Welsh red meat is facing increasing competition within the UK and global red meat industries, from other protein sources and from other protected food name products, so Welsh red meat should not rely on provenance alone to sustain market advantage. This issue, identified prior to Brexit, has been further exacerbated by the uncertainty surrounding the UK's departure from the European Union and the development of new trade deals.

BeefQ, through the testing and demonstration of an eating quality grading system and improved information sharing within the supply chain (to facilitate selection of animals based on eating quality traits), provides the tools required by the Welsh beef industry to improve the consistency of quality of Welsh Beef and create a differential advantage to not only maximise opportunities at the retail end of the supply chain, but which could also result in a step change in the payment basis for beef animals in Wales. The Welsh Beef Sector Review (2014) identified eating quality as the biggest barrier to purchase and consumer research on the willingness to pay for eating quality shows that consumers will pay higher prices for better eating quality grades. In Australia the MSA eating quality-grading system has generated substantial premiums for producers, wholesalers and retailers. The BeefQ project, through its activities with farmers, processors and consumers, encourages a shift in awareness that an animal and resulting carcase represent the sum of a large number of diverse consumer meal experiences rather than being a uniform single product. This change in focus will drive a strong consumer value focused industry culture able to be directly linked to payment at each point.

Another constraint to achieving the Welsh red meat industry's strategic objectives is that the industry continues to be slow to embrace innovation and adopt technical best practice. In BeefQ, the research and pre-competitive industry collaboration offers a perfect opportunity for the industry to play an instrumental role in the development and implementation of a new process in the red meat supply chain which could result in a fundamental change toward more consumer-focused and higher value production.

This report highlights the key activities undertaken in the BeefQ project. These activities include the eating quality grader training, carcase survey, consumer testing, stakeholder survey and engagement activities and the EQ grading case study. Recommendations are made by the project as to how eating quality can be moved forward in the UK post the BeefQ project, include how to access the required resources for implementing eating quality grading either commercially or for research purposes.

The interventions undertaken in BeefQ and laid out in this document are market-driven, integrated and support the beef industry to improve beef eating quality, profitability and the technical efficiency required to evolve a thriving, resilient and more sustainable red meat industry. Critically it can deliver a consumer focus and insight across supply chain sectors encouraging a more efficient, collaborative and relevant structure.

3 Skill development – Eating quality grader training

An important component of the BeefQ program, regarded as a legacy investment, was the inclusion of a meat science course delivered over 10 days in conjunction with practical training in chiller assessment utilising UNECE[1] protocols. The meat science course was delivered by Professor John Thompson and Dr Rod Polkinghorne (BeefQ partner Birkenwood Pty Ltd, Australia) with the course structure adapted from the Meat Standards Australia (MSA) meat science course delivered in Australia. Course participants were from 5 commercial meat processing plants across Wales and England and BeefQ partner Hybu Cig Cymru (HCC). The course content was designed to provide a meat science context to why specific carcase grading inputs including marbling, sex, ossification, carcase weight, pH, muscle, carcase suspension method, maturation and cooking method contributed to eating quality and how these interacted. The objective was to provide context to the reason for including these factors in predicting eating quality with discussion to relate other practices including breeds, growth rate, transport, lairage handling, slaughter and chilling practices to subsequent eating quality risk management or optimisation.

Image 1. BeefQ eating quality assessment training, January 2019

Practical training in assessing key factors including marbling, ossification, hump height, rib fat and pH were conducted by Ben Robinson the senior training officer with AUSMEAT, the holder of eating quality standards for the Australian industry. Training material and equipment including marbling chips, ossification charts, torch and meat and fat colour standards were supplied for the course. A computerised training system, OsCap, was also provided to assist in training. The OsCap system provides online training and is also utilised to retain grader skills with successful test results required every 8 weeks to maintain grader accreditation.

The original objective of obtaining chiller assessment accreditation for course participants was not achieved due to insufficient carcasses being available for practice and training but each participant gained a thorough understanding of the procedures. Recent approval of the International Meat Research 3G Foundation[2] (IMR3GF) as a training provider in Europe will enable course participants

[1] UNECE provides international standards for meat (bovine carcasses, cuts and eating quality assessment variables UNECE Standards for Meat | UNECE

[2] The International Meat Research 3G Foundation (IMR3GF) provides training and resources to conduct eating quality assessment for research and commercial purposes https://imr3g.org

and others) to continue training and be accredited at any time, together with providing access to the standards.

4 Carcase Survey - establishing the baseline for eating quality

4.1 Methodology

The purpose of the carcase survey was threefold: to characterise the population of beef going through PGI Welsh Beef approved processing plants, to identify a representative sample of cattle for consumer testing and to determine if information currently recorded on the cattle passport and the EUROP classification system could be used as suitable proxies for UNECE grading input data.

Full UNECE grading input data (ossification, marbling, eye muscle area, rib fat depth, hump height, ultimate pH), EUROP classification and carcase weight, passport age and breed data was collected on 1,037 carcasses in February 2019 across 6 factories with cuts for consumer testing taken from 2 factories. In August 2019, a further 1,053 carcasses were graded across 5 factories from which cuts for consumer testing were collected from 3. In total, data was collected from 2,090 carcasses in 8 factories and cuts collected for consumer testing from 5 factories.

Grading was conducted by Murray Patrick, a senior grader and compliance officer with Meat Standards Australia (MSA), with in plant assistance from those individuals who had previously undertaken grader training under the BeefQ project. UNECE protocols were used for eating quality grading data collection to ensure that Welsh data could be compared to and, if desired, merged with a large body of existing international data related to consumer sensory perception, animal and muscle characteristics.

4.2 Results

4.2.1 Survey population characteristics

An extreme range of 69 breeds and crosses were represented in the sample (Table 1), underlining the diversity within the cattle population and the challenge faced to utilise breed within potential eating quality estimation procedures.

Table 1 Cattle passport breed counts by survey month

BREED	Feb	Aug	ALL	BREED	Feb	Aug	ALL
Aberdeen Angus	0	7	7	Jersey	0	2	2
Aberdeen Angus Cross	6	63	69	Limousin	144	51	195
Ayrshire	2	4	6	Limousin Cross	91	260	351
Bazadaise	3	0	3	Lincoln Red	0	1	1
Bazadaise Cross	1	0	1	Lincoln Red Cross	2	0	2
Beef Shorthorn	4	0	4	Longhorn	0	1	1
Beef Shorthorn Cross	1	6	7	Luing	1	0	1
Belgian Blue	0	1	1	Meuse Rhine Issel	1	2	3
Belgian Blue Cross	0	7	7	Meuse Rhine Issel Cross	0	1	1
Belted Galloway	0	2	2	Montbeliarde	1	1	2
Blonde D'Aquitaine	1	7	8	Montbeliarde Cross	11	5	16
Blonde D'Aquitaine Cross	10	16	26	Norwegian Red Cross	5	6	11
British Blue	91	12	103	Other Dairy	0	7	7
British Blue Cross	42	120	162	Parthenais	0	2	2
British Friesian	58	20	78	Parthenais Cross	0	2	2
British Friesian Cross	10	5	15	Salers	0	5	5
Brown Swiss Cross	3	0	3	Salers Cross	2	9	11
Charolais	2	5	7	Shetland Cross	1	0	1
Charolais Cross	133	136	269	Shorthorn Cross	0	4	4
Cross Breed Dairy	2	0	2	Simmental	7	5	12
Dairy Shorthorn	1	0	1	Simmental Cross	52	30	82
Danish Red	1	0	1	South Devon	3	3	6
Devon	2	0	2	South Devon Cross	11	1	12
Devon Cross	0	1	1	Stabiliser	1	54	55
Flekvieh	6	0	6	Stabiliser Cross	5	17	22
Flekvieh Cross	2	1	3	Sussex Cross	1	0	1
Galloway	0	1	1	Swedish Red and White	2	0	2
Gelbvieh	0	1	1	Swedish Red and White Crc	0	1	1
Gelbvieh Cross	1	0	1	Swedish Red Cross	2	0	2
Hereford	13	6	19	Wagyu	0	1	1
Hereford Cross	72	37	109	Wagyu Cross	0	11	11
Holstein	31	18	49	Welsh Black	3	13	16
Holstein Cross	3	0	3	Welsh Black Cross	2	4	6
Holstein Friesian	148	71	219	Whitebred Shorthorn Cross	0	4	4
Holstein Friesian Cross	19	3	22	**TOTAL**	**1016**	**1053**	**2069**

A further challenge is the limitation with cattle passport breed coding where dam breed is indicated as X. Based on passport breed data for carcasses used for the consumer testing cut collection (Section 5) a considerable number classified as beef were most likely beef X dairy. Given the large number of breeds and crosses with very low numbers the passport breed data were consolidated into very notional beef and dairy categories within a broad sex categorisation with the resulting numbers shown in Table 2 and Table 3 below.

Table 2 Survey numbers by beef and dairy categories within survey month

	Feb	Aug	ALL
Beef	708	906	1614
Dairy	308	147	455
TOTAL	**1016**	**1053**	**2069**

Table 3 Table Categorisation by sex class within survey month

	Feb	Aug	ALL
Heifers	312	244	556
Cows	39	214	253
Steers	644	353	997
Young bulls	41	237	278
Mature bulls	1	5	6
TOTAL	**1037**	**1053**	**2090**

4.2.2 UNECE characteristics

4.2.2.1 Ossification

The average age within sex relative to the UNECE ossification bands are show in Table 4. It is clear there is a large sex effect on ossification development - young bulls reach an ossification level at a much younger age than heifers, which in turn are younger than steers, with a further trend for dairy steers and heifers to be older at most ossification levels. This highlights that numerical age, as identified on cattle passports, is not a useful proxy for ossification score in determining overall eating quality.

Table 4 Average age (days) by sex across ossification bands

Ossification	Cows		Heifers		Steers		Young Bulls		Mean for
	Beef	Dairy	Beef	Dairy	Beef	Dairy	Beef	Dairy	All
100	*	*	*	*	536	*	*	*	536
110	*	*	*	*	570	505	416	*	559
120	*	*	411	*	630	482	472	*	605
130	*	*	*	*	664	615	458	404	634
140	*	*	658	856	729	771	480	469	699
150	*	*	713	*	774	792	456	475	728
160	*	*	707	*	831	877	464	461	712
170	*	*	725	945	873	891	468	480	701
180	1710	*	746	883	857	953	471	451	734
190	*	*	753	872	884	973	468	473	743
200	1368	934	770	871	883	985	463	478	770
230	1254	1294	815	862	918	953	455	484	850
250	1326	1423	865	913	*	*	*	*	940
280	1467	1792	953	*	*	*	*	*	1335
300	1297	1575	1032	*	*	*	*	*	1281
350	2058	1909	968	1165	*	*	*	*	1907
400	2460	1787	835	*	666	*	*	*	2020
500	3219	2557	*	*	887	*	*	*	2919
590	3644	3365	*	*	*	*	*	*	3546
All	**2835**	**2316**	**756**	**886**	**747**	**791**	**468**	**467**	**949**

4.2.2.2 Marbling score

Marbling tended to be higher in dairy than beef breeds (Figure 1) and it is evident all categories encompass a considerable and overlapping range of marbling values with the young bulls at the lower end as may be expected.

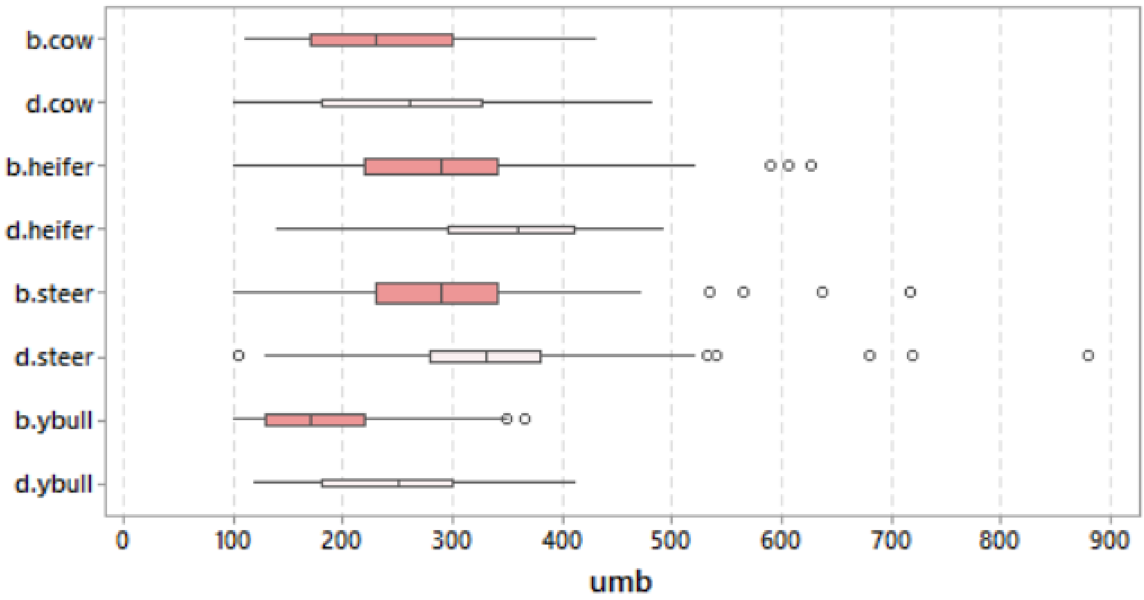


Figure 1 Distribution of UNECE marbling score (umb) within breed type (b=beef, d=dairy) and sex

There was some association between EUROP fat class and marbling (Figure 2) however the considerable range around any fat class makes it unsuitable to use a proxy. Figure 2 also indicates that marbling scores tended to be higher in the February data collection than in August across all categories. A general observation of seasonal marbling differences should be treated with caution as the distribution in part reflects a higher percentage of dairy breeds in the February data set (Table 2 above).

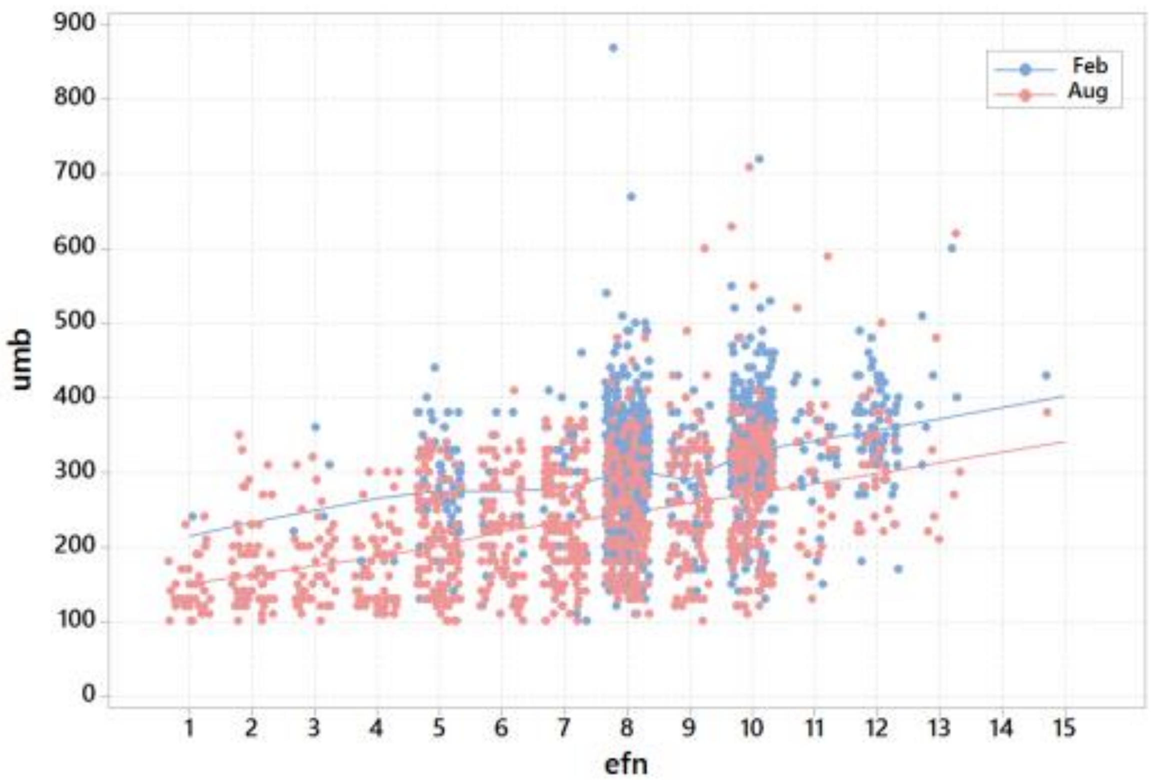


Figure 2 Relationship between UNECE marbling score (umb) and EUROP fat class (efn)

4.2.2.3 Rib fat

Rib fat depth at the 10th to 12th rib quartering site is a fatness measure utilised in conjunction with marbling in existing eating quality prediction models. Figure 3 indicates the slightly higher rib fat levels seen in dairy breeds, except for dairy cows. Again, there is a large range and overlap for all breed type and sex categories.

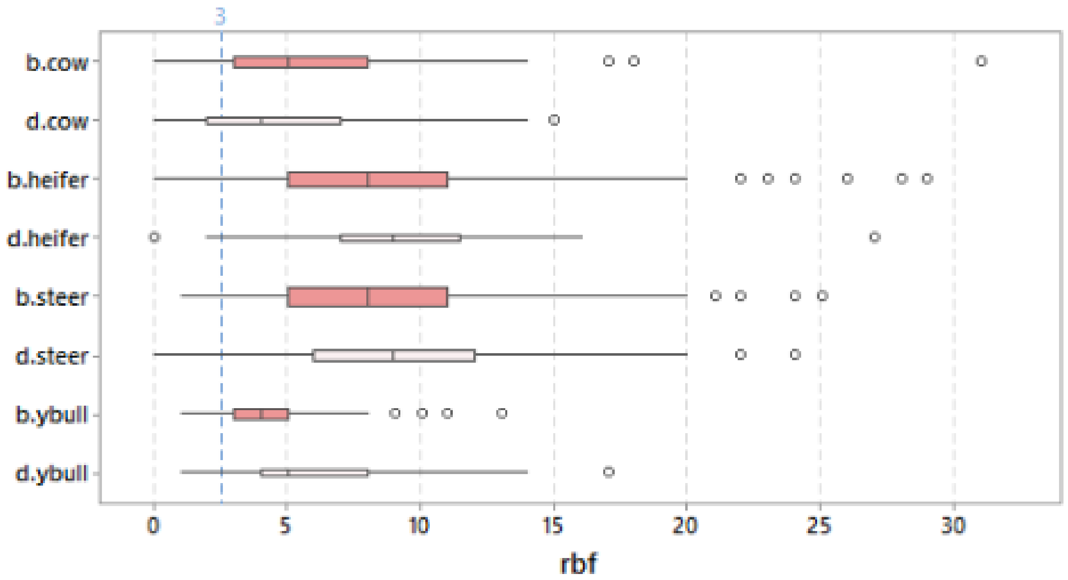


Figure 3 Rib fat (rbf) (mm) distribution for breed type (b=beef, d=dairy) within sex category. Dotted blue line labelled 3 indicates the minimum rib fat depth required to be eligible for grading under the Australian MSA model.

In the Australian MSA model a minimum 3mm of rib fat is required to be eligible for grading. This was imposed to facilitate more even temperature through muscles during carcase chilling and reduce the risk of muscle "two toning" and cold or heat shortening in exterior and interior muscle portions. Australian chilling regimes are generally aggressive and applied in conjunction with electrical stimulation to meet an MSA defined "abattoir window" where pH 6 must be achieved below 35˚C and above 12˚C. An insulating fat layer is regarded as useful in reducing muscle temperature gradients, particularly in external muscles exposed to direct air movement.

4.2.2.4 Hump Height

In the Australian MSA system hump height in relation to carcase weight and sex is used as a proxy for a negative *Bos Indicus* eating quality effect. While *Bos Indicus* content is not relevant to Wales (there is none), data has been collected for its possible value in indicating a "bull effect". It is assumed that a very young bull and steer cohort may have equivalent eating quality but diverge over time as the bull matures. Hypothetically hump relative to carcase weight may provide a graduation of the divergence and be useful in eating quality estimation. The greater hump values within the young bull category are evident in Figure 4 although further adjustment relative to carcase weight would be prudent and possibly breed type given the relationships in Figure 4. Clearly hump development interrelates with sex.

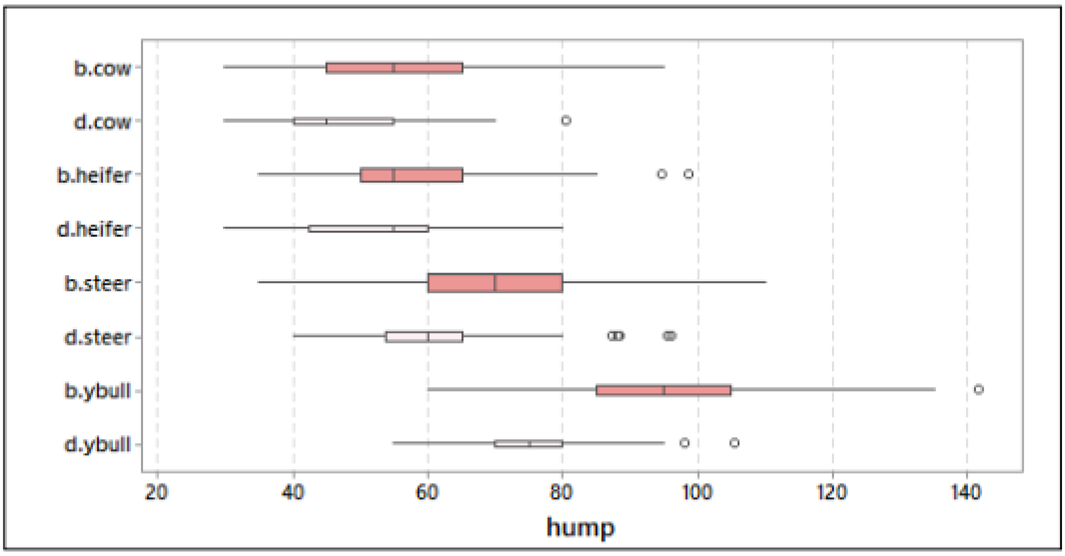


Figure 4 Hump height (mm) for breed type within sex

4.2.2.5 Ultimate pH and pH/temperature decline

Ultimate pH was recorded for all carcasses in the BeefQ survey with the distributions for breed type within sex shown in Figure 5. In the Australian MSA grading system, any carcase with an ultimate pH above 5.7 is excluded. This threshold was imposed to reduce the potential for more variable muscle quality, cooking performance and microbial growth at higher pH level. The majority of carcasses in the BeefQ survey fell below pH 5.7 but some carcasses were considerably higher.

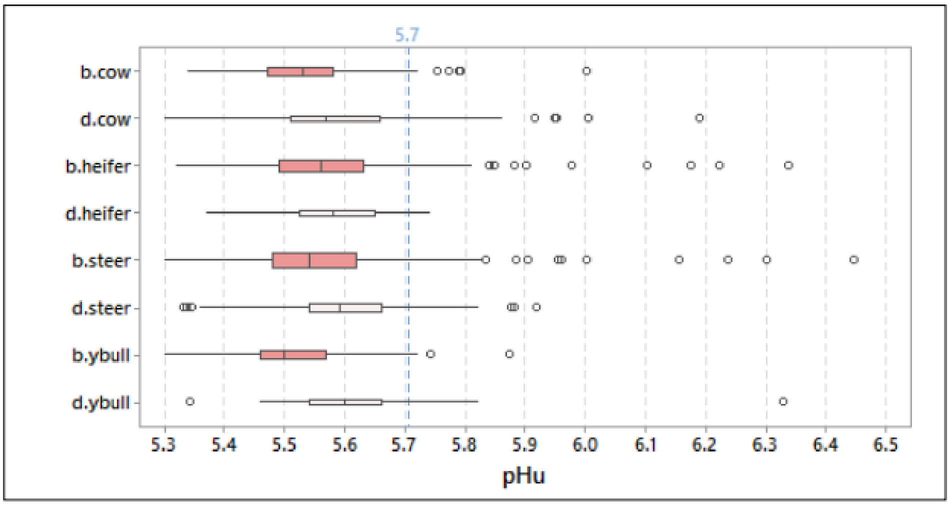


Figure 5 Ultimate loin pH by breed type within sex category

In addition to ultimate pH readings, pH and temperature decline data were recorded for all carcasses considered for BeefQ cut collection. Based on published data relating to cold and heat shortening risks MSA grading dictates that factory procedures be monitored, and where necessary adjusted, to ensure that a loin pH of 6.0 (regarded as a proxy for rigor mortis) is reached above 12˚C and below 35˚C to avoid, respectively, cold shortening and heat toughening. Cold shortened muscle is extremely tough and does not improve with maturation whereas high rigor temperature creates PSE (pale, soft and exudative) conditions associated with greater drip loss, a pale colour, watery appearance and reduced maturation potential due to ageing enzyme autolysis. The pH decline rate relative to temperature is a result of interactions between feeding pre-slaughter, carcase weight and fatness, electrical inputs (including restrainers, stimulators and hide puller rigidity probes) and refrigeration cycles. Typical adjustments to meet the "window" include changes to stimulator settings or modified chill cycles and may differ for grain fed cattle which generally have a far quicker pH decline than grass fed. pH decline data was collected on all carcasses presented for BeefQ cut collection with any outside the MSA defined abattoir window excluded. Due to time constraints and priority assigned to collecting grading input data only a minimal amount of pH decline data was collected from the survey population at participating factories.

4.2.2.6 EUROP and UNECE grading inputs

A correlation matrix of the EUROP and UNECE grading inputs was produced (Figure 6) to investigate potential relationships between current factory measured data in Wales (EUROP fat (Ef) and conformation (Ec), carcase weight (Cwt) and age) and potential additions common to existing eating quality models (hump height (hump), marbling (umb), ribfat depth (rbf), ossification (uoss), meat colour (amc), eye muscle area (ema)). Reasonable correlations are seen for age and ossification (uoss) along with some moderate relationships within fat measures and for carcase weight, eye muscle area and hump height. However, due to the variability observed in the UNECE variables across cattle type and sex (see previous sections) it is unlikely that any of the current factory measured data will be a reliable proxy for eating quality grading parameters.

	cwt	hump	Ef	umb	rbf	uoss	age	amc	Ec	ema
Cwt	1	0.54	0.01	-0.01	0.03	-0.09	-0.07	-0.19	0.58	0.39
Hump	0.54	1	-0.29	-0.12	-0.07	-0.27	-0.27	-0.21	0.54	0.54
Ef	0.01	-0.29	1	0.48	0.67	-0.11	-0.06	0.11	-0.06	-0.21
Umb	-0.01	-0.12	0.48	1	0.45	-0.12	-0.06	0.15	-0.18	-0.09
Rbf	0.03	-0.07	0.67	0.45	1	-0.16	-0.13	0.09	-0.05	0
Uoss	-0.09	-0.27	-0.11	-0.12	-0.16	1	0.87	0.26	-0.34	-0.13
Age	-0.07	-0.27	-0.06	-0.06	-0.13	0.87	1	0.27	-0.33	-0.11
Amc	-0.19	-0.21	0.11	0.15	0.09	0.26	0.27	1	-0.38	-0.07
Ec	0.58	0.54	-0.06	-0.18	-0.05	-0.34	-0.33	-0.38	1	0.42
Ema	0.39	0.54	-0.21	-0.09	0	-0.13	-0.11	-0.07	0.42	1

Figure 6 Correlation matrix of EUROP and UNECE measures in BeefQ carcase survey. Correlations of possible interest are coloured red.

5 Consumer Testing – Validating EQ prediction

The MSA grading model, used as the basis for eating quality prediction in the BeefQ project, is a dynamic model and modifications and adaptations can be made to the model to ensure accurate prediction of eating quality under different production environments and systems, such as those in Wales. To adapt the model for UK conditions, consumer taste testing of a subsample of beef, representative of that observed in the carcase survey (Section 4), was conducted using the standard protocol developed in Australia for the MSA system (Watson et al, 2008a and 2008b).

5.1 Approach

Twenty consumer taste panels were conducted at 18 different locations (Appendix 1) between September 30th, 2019, and February 26th, 2020. Each event included 60 consumers recruited locally with each only utilised once. This provided consumers who were "naive" to the taste testing process and the selected venues providing a relaxed semi formal testing atmosphere more akin to an in-home family meal than trained sensory panel booths. Consumers were eligible to participate if they were over the age of 18 and were consumers of beef. The primary approach to recruitment was to engage with Further Education Colleges teaching agriculture and or food service courses, supplemented by local sporting or food industry groups and Aberystwyth University. This approach provided an excellent range of consumer demographics and regional distribution across Wales and several locations in England. An unforeseen but important outcome of the consumer taste panel work was the strong engagement of the broader community, students and colleges with the BeefQ project and with sensory testing methodology.

Full BeefQ cut collection, sample fabrication and allocation for consumer testing protocols are detailed in Polkinghorne (unpublished). A brief overview is provided in the following sections.

5.1.1 Sample collection

A subsample of cuts from 60 carcasses was selected for consumer testing with these planned to represent a reasonable cross section of the cattle identified in the carcase survey. The ability to extrapolate sensory results from BeefQ consumer testing to the broader commercial cattle and beef cut population relies on acceptable correlation between the two, with the survey population of 2,090 head a much larger dataset although collected from carcasses made available for selection rather than a formally constructed sample. Analysis presented in Table 5 below indicates that the survey and sample means for most attributes are broadly similar for most criteria with age a little lower for the sample population and marbling slightly higher. More in-depth data analysis of individual attributes (Polkinghorne, unpublished) indicated significant overlap of means between the sample and survey populations and therefore it was concluded that results from the sample population could be reasonably applied to the survey population.

Table 5 Comparison of attribute Means within sex group between the survey (left column) and sample populations (right column)

	Bull		Cow		Heifer		Steer		Young Bull	
Dairy (%)	*17%*	*	*42%*	*67%*	*6%*	*0%*	*28%*	*8%*	*16%*	*0%*
EUROP Con	6.5	*	4.7	4.0	7.8	8.0	7.2	8.1	8.6	9.0
EUROP Fat	3.2	*	6.9	8.2	9.3	9.0	8.2	8.9	4.5	5.2
Carc. Kg	419	*	333	317	334	327	358	342	369	363
Age Days	1711	*	2629	1979	769	646	762	643	469	457
Ossification	337	*	455	412	191	181	148	137	161	174
Marbling	190	*	240	332	289	318	296	312	192	241
Meat Colour	3.8	*	3.3	4.8	2.6	2.6	2.6	2.5	1.9	2.4
Col reject%	*50%*	*	*37%*	*100%*	*19%*	*5%*	*20%*	*13%*	*7%*	*22%*
Ribfat	1.0	*	5.4	6.0	8.9	8.5	8.3	10.2	4.5	5.1
Rfat reject%	*100%*	*	*26%*	*0%*	*3%*	*0%*	*2%*	*0%*	*10%*	*11%*
Ultimate pH	5.60	*	5.56	5.56	5.57	5.54	5.56	5.57	5.53	5.46
pH reject%	*0%*	*	*11%*	*0%*	*4%*	*0%*	*5%*	*0%*	*3%*	*0%*
No in sample	**6**	**0**	**247**	**6**	**535**	**21**	**973**	**24**	**269**	**9**
Sample %	***0%***	***0%***	***12%***	***10%***	***26%***	***35%***	***48%***	***40%***	***13%***	***15%***

For consumer testing, BeefQ collected four cuts from 90 sides of beef (Table 6 and Table 7) which were evaluated as grilled steak by 1,200 consumers. These cuts, sirloin, tenderloin, salmon and featherblade, were selected to provide an expected range of eating quality. Further variation was introduced by comparing aitch bone (TX) and Achilles tendon (AT) carcase suspension methods within carcasses and by testing after 7 and 21 days maturation. Additional range was incorporated by collecting cuts in two seasons from cattle types typical of the Welsh herd in beef breed steers and heifers, dairy cross steers and heifers, young bulls and cows. The combinations and interactions inherent in this matrix of animal type, season, carcase suspension, muscle (cut) and maturation highlight the challenge of accurately predicting individual consumer meal outcomes.

*Table 6 BeefQ cattle and carcase side numbers for product collection**

Side Numbers				No of Cattle	
Cattle Type	**AT**	**TX**	**Sides**	**AT & TX**	**AT only**
1 Beef Steer	12	6	18	6	6
2 Beef Heifer	12	6	18	6	6
3 Beef x Dairy Steer	12	6	18	6	6
4 Beef x Dairy Heifer	9	6	15	6	3
5 Young Bull	9	6	15	6	3
6 Dairy Cow	6		6		6
Total Sides	60	30	**90**	**30**	**30**

Total of 60 Head
Total of 90 Sides

**AT = Achilles tendon carcase suspension, TX = aitch bone carcase suspension*

*Table 7 Muscles, suspension and maturation treatment combinations**

Cut Common Name	Muscle	Suspension	Maturation Days
Fillet / Tenderloin	*M.psoas major*	AT	7
			21
		TX	7
			21
Sirloin / Striploin	*M.longissimus dorsi lumborum*	AT	7
			21
		TX	7
			21
Salmon / Eye of Silverside	*M.semitendinosus*	AT	7
			21
		TX	7
			21
Featherblade	*M.infraspinatis*	AT	7
			21
		TX	7
			21

**AT = Achilles tendon carcase suspension, TX = aitch bone carcase suspension*

Five factories made the required cattle types available over the February and August collection periods. Suitable cattle meeting research requirements for sex and type were purchased by the factories on behalf of the project – excess cattle were purchased to enable choice. Kill times were recorded for cattle in each selected group and standard carcase data including EUROP classification obtained from the factory systems. All carcasses within the group were tagged to enable a final selection for cut collection after pH decline and grading data was available. Alternating left and right carcase sides were nominated for aitch bone (TX) and achilles (AT) carcase suspension methods and tagged accordingly. On the morning following slaughter one side of each carcase was ribbed between the 10th and 11th rib and allowed to bloom for a minimum of 30 minutes. UNECE/MSA grading data was collected for each carcase recording sex, carcase weight, hump height, ossification, AUS-MEAT and MSA marbling scores, eye muscle area, meat colour, fat colour, ultimate loin pH and temperature. Research personnel then selected sides to meet the agreed design (see Table 6 and Table 7) for the cattle type(s) pertinent to each factory, aiming for a spread of inputs, in particular marbling and ossification, and including breed types while avoiding carcasses with high pH, bruising or uneven fat distribution due to hide puller or processing damage. Laminated tickets were then pinned to each cut required for collection on each carcase. Carcase quarters were then transported to Celtica Foods Ltd for deboning into primals and subsequent sample fabrication.

5.1.2 Sample fabrication

All cuts were transported to Celtica Foods Ltd within 7 days of slaughter to enable fabrication and freezing at 7 days ageing where designated. Primals were fully denuded of fat and silverskin while retaining individual ID through the ticket which was placed on a tray adjacent to the cutting board. This process also required removal of any muscle portions other than the designated test muscle and the featherblade gristle seam. Consumer samples, each approximately 75 x 40mm and 25mm thick, were then prepared from each designated muscle position and labelled with a code that linked each individual consumer sample back to the originally graded carcase and its UNECE/MSA grading scores, cut, aging and hang method. These samples were then vacuum packed and frozen after appropriate aging (7 or 21 days). Single steak portions were prepared for REIMS chemistry analysis by Queens University Belfast (Section 6) utilising a second set of coded labels. These were also frozen and subsequently transported to Queens University Belfast.

5.1.3 Allocation of consumer samples

The frozen consumer samples allocated for sensory testing comprised 20 "picks", a pick requiring 60 consumers and 42 samples, each evaluated by 10 consumers. UNECE/MSA protocols (Watson et al., 2008a, Accessory Publication) designate that each consumer is served 7 samples in a designated order with the first sample, referred to as a "link", selected to be within an anticipated mid quality range and serving to orient each consumer prior to the following 6 test samples. The 36 non-link samples in each pick were assigned to 6 products, each of 6 individual samples. Samples were allocated to products on the basis of expected eating quality to ensure that each product was relatively uniform whereas there was considerable expected range between products. Typical pick designs therefore would have tenderloin samples assigned to Product 6, assumed to be rated highly, and salmon/eye round samples assigned to Product 1 on the expectation of low ratings. Other muscle samples were placed between these two extremes with consideration of anticipated muscle, treatment and maturation effects. A total of 20 picks were designed for sensory testing relating to 20 individual test sessions of 60 consumers (1200 in total). A typical pick design is shown in Table 8.

Table 8 Typical Pick design utilised in BeefQ consumer testing

	Link	Product 1	Product 2	Product 3	Product 4	Product 5	Product 6
1	STR	EYE. AT-7	EYE. TX-7	STR.AT-7	STR.TX-7	FB.TX-7	TDR.AT-7
2	STR	EYE. AT-21	EYE. TX-21	STR.AT-21	STR.TX-21	FB.TX-21	TDR.AT-21
3	STR	EYE. AT-7	STR.AT-7	STR.TX-7	FB.AT-7	FB.TX-7	TDR.AT-7
4	STR	EYE. AT-21	STR.AT-21	STR.TX-21	FB.AT-21	FB.TX-21	TDR.AT-21
5	STR	EYE. TX-7	STR.AT-7	STR.TX-7	FB.AT-7	TDR.TX-7	TDR.TX-7
6	STR	EYE. TX-21	STR.AT-21	STR.TX-21	FB.AT-21	TDR.TX-21	TDR.TX-21

** STR=Striploin, EYE=Eye Round/Salmon, FB=Featherblade, TDR=Tenderloin
AT=Achilles hang, TX=Aitch Bone hang, 7 & 21 = Maturation days

The design provided an expected eating quality range within each pick and connection of cuts, treatments (hang and ageing) within animals from different collection times and factories. This provided an excellent interrelated base from which consumers sensory response was established and related to factors that impact the response and that could be utilised in prediction. To avoid potential halo (scores affected by prior sample) or order (serving order from 2nd to 7th) effects the testing protocol utilised a 6 x 6 Latin square to ensure that each product was served an equal number of times in each of positions 2 to 7 and equally before and after each of the other 5 products. Ten consumers evaluated each sample with each also served in 5 different serving orders and to 5 different subsets of 12 consumers within the 60 to spread the sample across the three serving sessions of 20 people.

5.1.4 Consumer event protocol

The thawing, preparation, cooking and serving protocol for MSA consumer sensory testing (Gee et al., 2010) was followed. A modification of the standard consumer questionnaire used in all MSA sensory trials was developed and can be viewed in Appendix 2 below together with a sample score sheet (Appendix 3). Each questionnaire was stapled to 7 sample score sheets, all of which had a software produced unique pre-printed alphanumeric code attached on a sticky label. These codes and the control software provided linkage to all stages of product collection, preparation, cooking and serving. BeefQ personnel entered all the consumer data into provided Excel files. The demographic questions were coded according to the tick box options and the line scales measured in mm with the category box coded 2 (unsatisfactory), 3, 4 or 5 (premium). All the scoring data was independently measured and keyed by two people and checks made for any discrepancy greater than 1 mm with these remeasured and corrected.

5.1.5 Consumer data analysis

Analysis of the data was conducted by Dr Ray Watson, originator of the MQ4 scoring process and subsequent utilisation in prediction modelling (Watson et.al 2008), on behalf of Birkenwood Pty Ltd. Statistical procedures followed (discriminate analysis) were identical to those published and utilised in prior sensory studies (e.g., Polkinghorne et al, 2011). The discriminate analysis determines the relationship between the individual scales (tenderness, juiciness, flavour and overall liking) and the category box selected. This provides a measure of the relative importance of each scale in determining the final quality decision.

The "overall liking" scale is somewhat different to the other three and something akin to a combination of them. In this way overall liking may predominantly reflect, say, tenderness at one extreme and flavour at another. The combination of all four has been found to provide a superior relationship to the category selection across consumer groups. To clarify the scale interactions two analyses were conducted, the first (SQ4) utilising the four scales including overall liking and the second (SQ3) only tenderness, juiciness and flavour in relation to category.

5.2 Results

5.2.1 Discriminate analysis of the sensory data

Within Table 9 the row of values to the right of tn (tenderness) within the SQ4 and SQ3 blocks reflects in order the weighting of tenderness at each category division; 0.21 (21%) at the unsatisfactory/good everyday or 3* boundary, 0.29 at the 3*/4* and 0.26 at the 4*/5* for the SQ4 and similarly for ju (juiciness), fl (flavour) and ov (overall liking) with the total of the four scales always 1 (100%). The values to the right (0.25 for tn etc) are the average weighting across all categories.

Table 9 Three (SQ3) and four (SQ4) scale results from discriminate analysis of sensory data

SQ4					SQ3					MQ*
0.707	36.3	60.4	78.8		0.680	37.3	59.8	77.8		
tn	0.21	0.29	0.26	0.25	tn	0.38	0.45	0.36	0.40	0.32
ju	0.02	0.04	0.11	0.06	ju	0.12	0.14	0.18	0.15	0.10
fl	0.11	0.04	0.21	0.12	fl	0.50	0.40	0.46	0.46	0.29
ov	0.67	0.62	0.42	0.57						0.29
MQ										
0.699	36.8	60.3	78.6							

The values above the cut off weightings are the statistically derived cut off scores that best segregate the quality groups: good every day (3*), better than everyday 4* and premium 5* (36.3, 60.4 and 78.8, respectively for SQ4 and 37.3, 59.8 and 77.8 for SQ3). The 0.707 figure immediately under SQ4 is the proportion of times the weightings correctly allocated the individual consumer category choice. This has nothing to do with prediction as it purely reflects genuine consumer variance. The 70.7% figure is at the high end of previous studies with a high 60's result typical and sufficiently accurate to enable quality segregation. (It should be noted that a score 1 point above or below a cut-off is a fail and that in practice a "low or high scorer" may typically be consistently above or below the population cut offs) improving the notional accuracy. The results indicate that the BeefQ consumer population consistently scored beef across a broad quality range.

For the SQ4 analysis it is seen (typically) that overall has the greatest weighting with juiciness the lowest (Table 9). When SQ3 is evaluated, the proportion previously allocated to overall is transferred to the other three scales with flavour most increased followed by tenderness and juiciness a low last. This result is also not unusual although tenderness is sometimes more critical at the low end and flavour at the high. It is noted that the discriminate accuracy is reduced to 0.68 (68%) with overall removed. The MQ* values are the midpoint between the SQ4 and SQ3 values and also total to 1 (100%). These are the most suitable weightings for these set of data with the same weighting for each scale used at each level. In practice this provides a simple process that can be applied across a full range of cuts and carcasses.

As any set of data will marginally vary, the scores have been rounded to a (0.3 Tender+0.1 juiciness+0.3 flavour+0.3 overall) to produce the MQ4 value at the table base with associated cut offs of 36.8, 60.3 and 78.6. When these values and weightings are applied to the data 69.9% discrimination is obtained, very close to the optimum possible and practically usable across other data. The weightings are almost identical to current MSA 30:10:30:30 ratios (Bonny et al., 2017) indicating that the two consumer populations are similar in this regard. The cut off scores for 3* and 5*, respectively, are slightly lower (37 vs 41) and slightly higher (79 vs 77) than current MSA values which indicates that BeefQ consumers have utilised the scales more fully and may discriminate more for both unsatisfactory and premium beef. This has important ramifications for brands where any inconsistency may impact value.

The dot plot below (Figure 7) shows all values including some that would appear unlikely (Unsatisfactory and >80 MQ4 and 5* Premium with MQ4 of 5 etc), possibly reflecting a misunderstanding of the scales. The vertical lines are the calculated cut off values with the distribution outside the lines reflecting the % of consumers with lower or higher judgement. Any official grade, or commercial brand standard can be moved either way to either reduce risk (less product harvested) or increase supply. In the MSA system a grading cut off of 45.5 is applied to reduce the risk of failure at or near the statistical 41 point value.

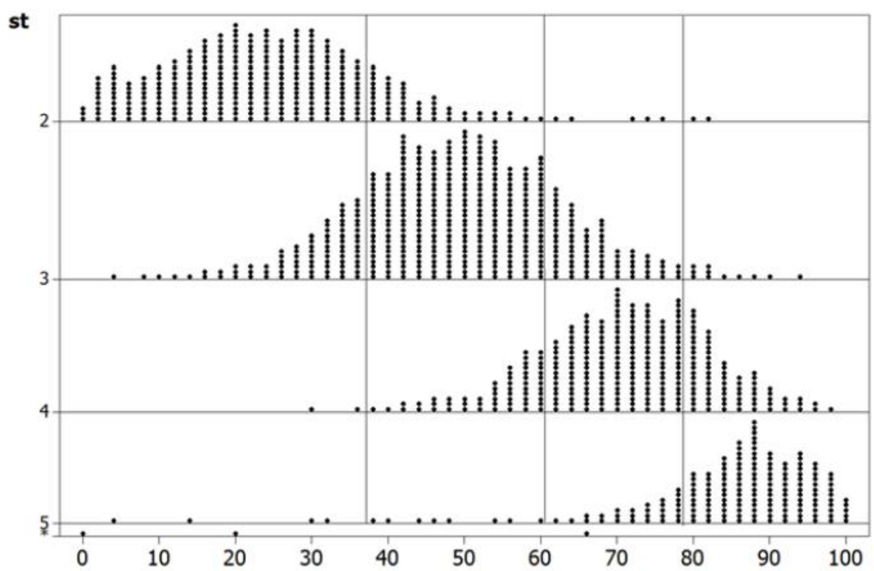


Figure 7 Dot plots of MQ4 against category for BeefQ consumers*

** 2=unsatisfactory, 3=good everyday, 4=better than everyday, 5=premium*

These analyses provide strong evidence that Welsh and English consumers clearly differentiate eating quality into 4 distinct categories from unsatisfactory to premium and that a universal set of sensory weightings and cut off values can adequately define these categories.

It is recommended that an MQ4 statistic based on 30% Tenderness + 10% Juiciness + 30% Flavour + 30% Overall be adopted. MQ4 cut off values to define Unsatisfactory, Good Everyday (3*), Better than Everyday (4*) and Premium (5*) should be set to reflect consumer judgement and an Industry agreed failure risk at the unsatisfactory/3* boundary. Cut offs of 40.5 (providing a buffer against consumer dissatisfaction), 60.5 and 78.5 are recommended for consideration.

5.2.2 Willingness to pay

At the completion of tasting their 7 samples each consumer was asked to complete a willingness to pay form (Appendix 4). By again marking across each line scale the consumer indicated a price they regarded as value, based on the relevant category choice (the same as used for previous samples). The question did not seek to price the actual samples consumed but rather beef of the category indicated. Most were expected to have allocated their actual samples to most or all categories but were not expected to clearly remember “sample 2 etc”.

The consumers were also asked to record if they were the regular purchaser of beef in their household. Again all scores were measured in mm and converted to £ per kg then cross checked by independent double entry.

A simple average of all scores provided average values per kg as shown in Table 10 together with ratios of each quality band relative to 3* Good Everyday beef.

Table 10 Willingness to pay raw means and ratios for 1,200 BeefQ consumers

	Unsatisfactory	**Good Everyday (3*)**	**Better than Everyday (4*)**	**Premium (5*)**
Price£/kg	£4.25	£9.99	£15.42	£22.09
% of 3*	43%	100%	154%	221%

While the raw means provide an indication that there are substantial differences recorded for beef of different quality they do not convey the range within the observations. In particular in the unsatisfactory where 72 (6.0%) of consumers entered a price of £0 with 218 (18.2%) recording a value of £1 / kg or less indicating that they are highly unlikely to buy beef of that quality regardless of price.

The demand curves in Figure 8 provide a more detailed picture. The horizontal axis represents the £/kg and the vertical axis the proportion of consumers (from the sample of 1200) who were prepared to buy beef of each quality level at that price. For example, at £10 only 6% were prepared to buy Unsatisfactory, 50% were prepared to buy Good Everyday (3*), 82% Better than Everyday (4*) and 94% Premium (5*) at that price. The value trade-off between eating quality and price is stark providing a strong indication that consistent eating quality would be related to significantly different price points.

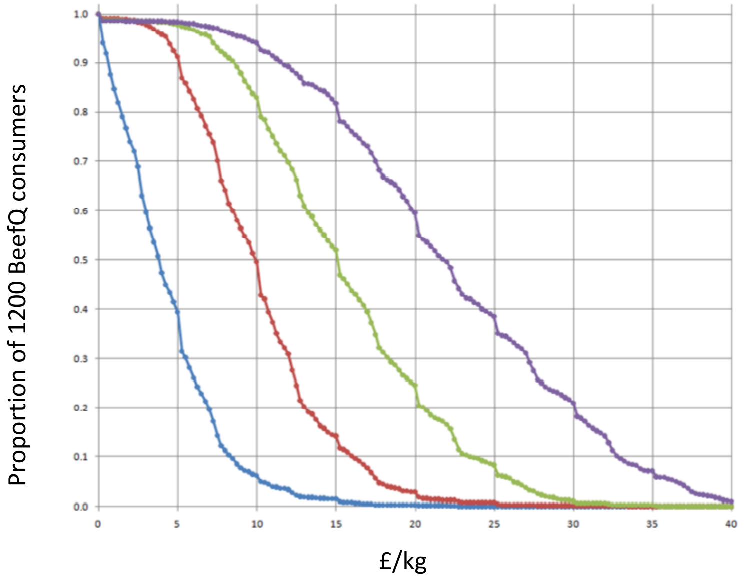


Figure 8 Demand curves for beef of Unsatisfactory (blue), Good Everyday (red), Better than Everyday (green) and Premium quality (purple)

There are legitimate questions as to how conversant consumers were with price expressed in £/kg, a regular comment being that they may be more conversant with a price per pack. More detailed analysis of the data (not presented) indicated that there appeared to be little if any difference in pricing response between consumers identified as purchasers and non-purchasers of beef. It should be remembered that asking for a price response is different to actually paying so any WTP data should be interpreted with caution, and more so in quoting actual values for the reasons mentioned and as price is dynamic over time. The ratios and relationships between quality levels are however believed to be indicative and emphasise the potential revenue gain from embracing a description system that accurately relates eating satisfaction with price to provide direct value choices.

5.2.3 Are eating quality judgements influenced by demographic variables?

In this analysis the recommended MQ4 construction of 0.3 tend + 0.1 juicy + 0.3 flav + 0.3 overall (the response variable) was related to principal demographic criteria from the BeefQ consumer data. An initial statistical model of MQ4 = EQSRef (the sample ID) + age + income for example examined relationship of consumer age and annual household income. The model in effect tests for a hypothetical MQ4 value for a particular sample (indicated by the EQSRef effect) but that the consumer’s response is modified away from this value by their age and their income level, and random error. The effect size is effectively the MQ4 variation for a given WTP value for an age group or income level thus the difference between young and old people is estimated to be around 2 to 3 MQ4 points. Table 11 displays the effects produced when this model is fitted.

Table 11 Estimated effect of consumer age and income on Willingness to Pay

Age	Effect	n	Income	Effect	n
18-19	1.00	81	-25	3.07	205
20-25	1.99	141	25-50	0.28	466
26-30	0.08	122	50-75	-0.63	324
31-39	-1.24	162	75-100	-1.35	109
40-60	-1.10	463	100+	-1.37	74
61+	-0.75	227			

Due to low numbers the lowest and highest income brackets in the survey were combined. As shown, there was a tendency to "mark harder", i.e., to tend to give lower values to MQ4 as age increased and also as income increased. While these results were statistically significant the large sample size increases the likelihood of significance so should also be regarded as indicative and viewed in relation to practical importance. While one might think there is a direct connection between these results it appears not as, for these data, age and income are effectively uncorrelated (r = -0.03).

Fitting further models suggested that only age, income and preference (i.e., level of cooking doneness) demographics had any effect. In the case of preference, the hard markers were at the rare end of the scale. There was nothing of interest for gender, statement (attitude to red meat consumption), frequency of eating, heritage or number of children but a hint of an effect for the number of adults in a house suggesting that higher numbers tended to give higher scores, possibly reflecting young apartment dwellers.

5.3 BeefQ Sensory Product Results and Analysis

Sensory results were collated from BeefQ testing with the 20 picks providing data on 720 individual test samples plus a further 120 tested as "Link", each evaluated by 10 consumers (see section 5.1.3 for detail). While the Link samples and all consumer scores were included in the consumer data analysis only the 720 test samples were utilised for product evaluation. The measure used for analysis and comparison was the clipped MQ4 value. The 720 samples were made up from 180 samples from each of the Tenderloin (TDR062), Striploin (STR045), Eye Round (EYE075) and Featherblade (OYS036). Seven- and twenty-one-days ageing was applied equally within the 180 samples from each cut. Aitch bone (TX) and Achilles carcase (AT) suspension was also compared for all cattle types other than the old cows which were only Achilles hung. Table 12 displays the raw mean scores for hang method and ageing period within each cut. The spread of data within each is displayed in the Figure 9 box plots.

Table 12 Mean MQ4 values for hang and ageing treatments within muscle**

EYE075	AT	TX	ALL
7	30.8	34.7	32.1
	60	*30*	*90*
21	32.8	37.2	34.3
	60	*30*	*90*
All	32.8	37.2	34.3
	120	*60*	*180*
OYS036	AT	TX	ALL
7	59.7	62.3	60.6
	60	*30*	*90*
21	58.8	60.9	59.5
	60	*30*	*90*
All	59.3	61.6	60.1
	120	*60*	*180*

STR045	AT	TX	ALL
7	48.1	60.4	52.1
	61	*30*	*91*
21	56	60.2	57.4
	60	*30*	*90*
All	52	60.3	54.7
	121	*60*	*181*
TDR062	AT	TX	ALL
7	70.7	66.2	69.2
	60	*30*	*90*
21	72.5	64.9	70.0
	59	*30*	*89*
All	71.6	65.6	69.6
	119	*60*	*179*

**AT = Achilles tendon carcase suspension, TX = aitch bone carcase suspension, Tenderloin (TDR062), Striploin (STR045), Eye Round (EYE075) and Featherblade (OYS036). Figures in grey are the number of samples for each cut x treatment.*

The data above (Table 12) indicate there is an interaction between muscle, aging and hang method. Aging to 21 days has positive effect on the MQ4 score of eye round and a strong positive effect on Achilles suspended (AT) striploin, but has a slight negative effect on aitch bone suspended tenderloin and feather blade. Similarly, aitch bone carcase hanging (TX) has a positive effect on the MQ4 score of striploin, but a negative impact on the MQ4 score of tenderloin. These results are consistent with the findings of other studies (Park *et al.*, 2008, Devlin et al., 2017) and highlight the importance of considering the value of individual muscle groups when applying different aging and hang methods.

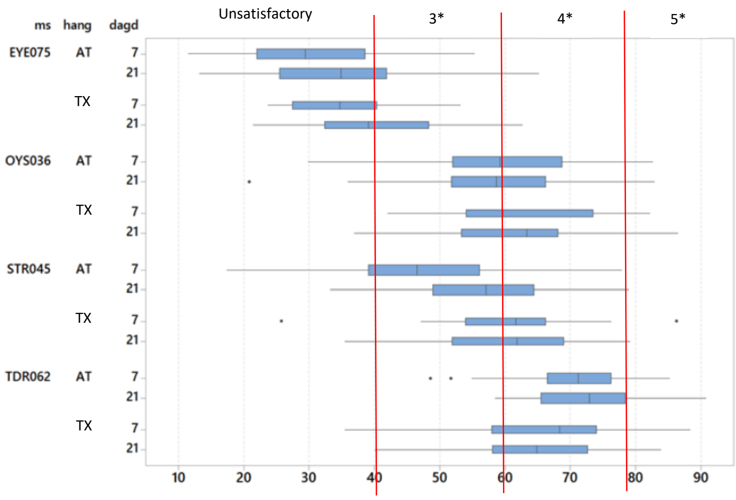


Figure 9 Distribution of MQ4 values by hang (AT = Achilles tendon carcase suspension, TX = aitch bone carcase suspension) and ageing days (dagd) within muscle (Tenderloin (TDR062), Striploin (STR045), Eye Round (EYE075) and Feather blade (OYS036)). Red lines indicate suggested cut off values for Good Everyday (3), Better than Everyday (4*) and Premium (5*) eating quality.*

In Figure 9, the central blue box contains 50% of the data, with half lying either side of the median value indicated by the vertical line. The two thin tails each represent the extreme 25% at the low and high ends. The width of each box is proportional to the number of observations in the category. As displayed, each of the plots encompasses a very large range, typically 30 to 50 MQ4 points. There is also extensive MQ4 overlap across cuts indicating the impossibility of deducing eating quality by cut name alone. If the population is divided at the 40, 60 and 78 lines (Figure 9), indicated as suitable division points for notional grades, this cut based variation is reduced to a maximum 20 points, providing a far more consistent consumer experience and the unsatisfactory tail is removed. In practice alternative cooking methods, ageing, and processing, with mincing a practical last step, would be used to address the unsatisfactory product. Individual brands may also elect to adopt alternative MQ4 cut off points for either all product or for individual cuts. This could be activated to either place a desired % of supply within a brand category or to deliver a common cooked experience across all product, reducing the dependence on cut as a retail descriptor.

6 An evaluation of sensory quality of beef muscles using consumer responses and Rapid Evaporative Ionisation Mass Spectrometry (REIMS) analysis

This piece of work was conducted in parallel to the consumer taste panel tests described in Section 5. A subsample of the consumer samples was selected, frozen and delivered to Queens University Belfast (QUB) where they were analysed using Rapid Evaporative Ionisation Mass Spectrometry (REIMS) technology. The data collected using REIMS was correlated with the results of the consumer taste testing to identify if REIMS technology has the potential to predict the eating quality of raw meat samples. This research, conducted by Wenyang Jia, Lynda Perkins, Nigel Scollan at QUB builds on research recently published which show promise for the technology using a slightly different approach to consumer taste testing (Zhai et al., 2022).

6.1 Introduction

Sensory evaluation of meat measures consumer reactions to product quality. The most common traits used in evaluating the sensory quality of red meat include tenderness, juiciness, flavour and overall liking (Ruiz-Capillas et al., 2021). These traits are directly influenced by animal age, breed, sex, feed and post-slaughter conditions such as ageing and hang method (Khan et al., 2015). An approach to provide sensory quality data as a quality control stage post-slaughter, but prior to retail is in demand, although establishing a rapid correlation between the raw meat and the sensory parameters is challenging given lack of scientific evidence and practicality in meat production lines.

Rapid Evaporative Ionisation Mass Spectrometry (REIMS) is an ambient pressure ionisation technique that allows rapid sampling of an unprocessed sample followed by mass spectral fingerprinting (Barlow et al., 2021). REIMS has been used as a powerful analytical tool in food fraud and adulteration of meat products (Robson et al., 2022). More recently, REIMS has been used to determine the sensory and nutritional quality parameters of beef (Zhai et al., 2022). However, studies assessing and linking lipidomic output from REIMS and consumer responses to beef sensory quality are limited. Therefore, this experiment used REIMS and advanced chemometric modelling to uniquely connect lipidomic data from raw beef and the sensory scores from consumers.

6.2 Material and methods

6.2.1 Sample collection

Beef samples (N=149) were collected from 31 carcasses after 7-day maturation post-slaughter. Carcasses including 12 breeds and three feeding systems, were hung using the Achilles Tendon (AT) method across three sites in Wales (August 2019; Table 13). Four muscle samples were collected including: Oyster blade (OYS; n=32), Tenderloin (TDR; n=32), Ribeye (EYE; n=32), Striploin (STR; n=53). After processing, all muscles samples were transported to Queen's University Belfast (QUB) and stored at -20 until REIMS analysis.

Table 13 Slaughtering information of all samples

Abattoir	Kill Date	BREED			CUT
ABP Ellesmere	05/08/19	LIMX (Limousin Cross)	LIM (Limousin)	SAX (Salers Cross)	OYS
Dunbia Preston	07/08/19	HEX (Hereford Cross)	BRB (British Blue)	WB (Welsh Black)	TDR
RPF Llanidoes	09/08/19	AAX (Aberdeen Angus Cross)	BRBX (British Blue Cross)	BFX (British Friesian Cross)	EYE
		ST (Stabiliser)	CHX (Charolais Cross)		STR

6.2.2 REIMS analysis

The REIMS system includes: a Waters REIMS source (Waters Corporation, Wilmslow, UK); a Xevo G2-XS QTof Mass spectrometer (Waters Corporation, Wilmslow, UK); a monopolar electrosurgical knife (Model PS01–63H, Hangzhou medstar Technology Co, Ltd, Jiaxing City, China); and an Erbe VIO 50 C generator (Erbe Medical UK, Leeds, UK) (Electrosurgical dissection) which was set to 40 W.

Beef samples were burned using the electrosurgical "iKnife", which generated a vapour which is then analysed immediately by the mass spectrometer. Data were performed in sensitivity mode with continuum data acquisition in negative ionisation mode within a mass range of m/z 50-1200, with a scan speed of 2 scans per second. Each sample (1 cm in thickness) was analysed four times. REIMS data was extracted using the Abstract model builder software (Waters Research Centre, Budapest, Hungary) and binned with an interval of 0.5 Da, 0.25 Da, and 0.05 Da respectively.

6.2.3 REIMS data processing

Data processing was conducted to explore the optimal and non-overfitting model after three steps 1) raw data input 2) data pre-treatment, and 3) regression analysis (Figure 10). The strategy regarding the data pre-treatment, 144 attempts (8 pre-processing methods* 6 m/z range * 3 mass bin) were tested, and a combination of "one data pre-processing + one mass range + one mass bin" was used as an optimal solution for data pre-treatment (Table 14 Components of data pre-treatment strategy).

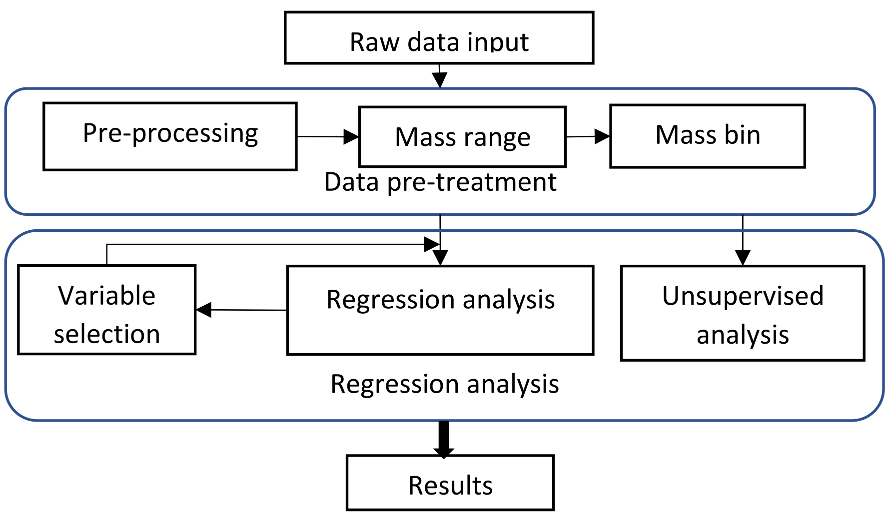


Figure 10 Data processing steps of REIMS output

Table 14 Components of data pre-treatment strategy

Pre-processing	Mass range (m/z)	Mass bin
Normalisation	50-1200 (whole mass range)	0.5 Da
Mean centre	100-900 (whole mass range)	0.25 Da
Normalisation + Mean centre	50-500 (fatty acid range)	0.05 Da
Normalisation + Mean centre + SNV (Standard Normal Variate)	100-500 (fatty acid range)	
Mean centre+ Parto scaling	600-900 (glycerophospholipids range)	
Mean centre + Smoothing SG + Normalization	600-1000 (glycerophospholipids range)	
Log 10 + Mean centre		
Min-Max scaling + Mean centre		

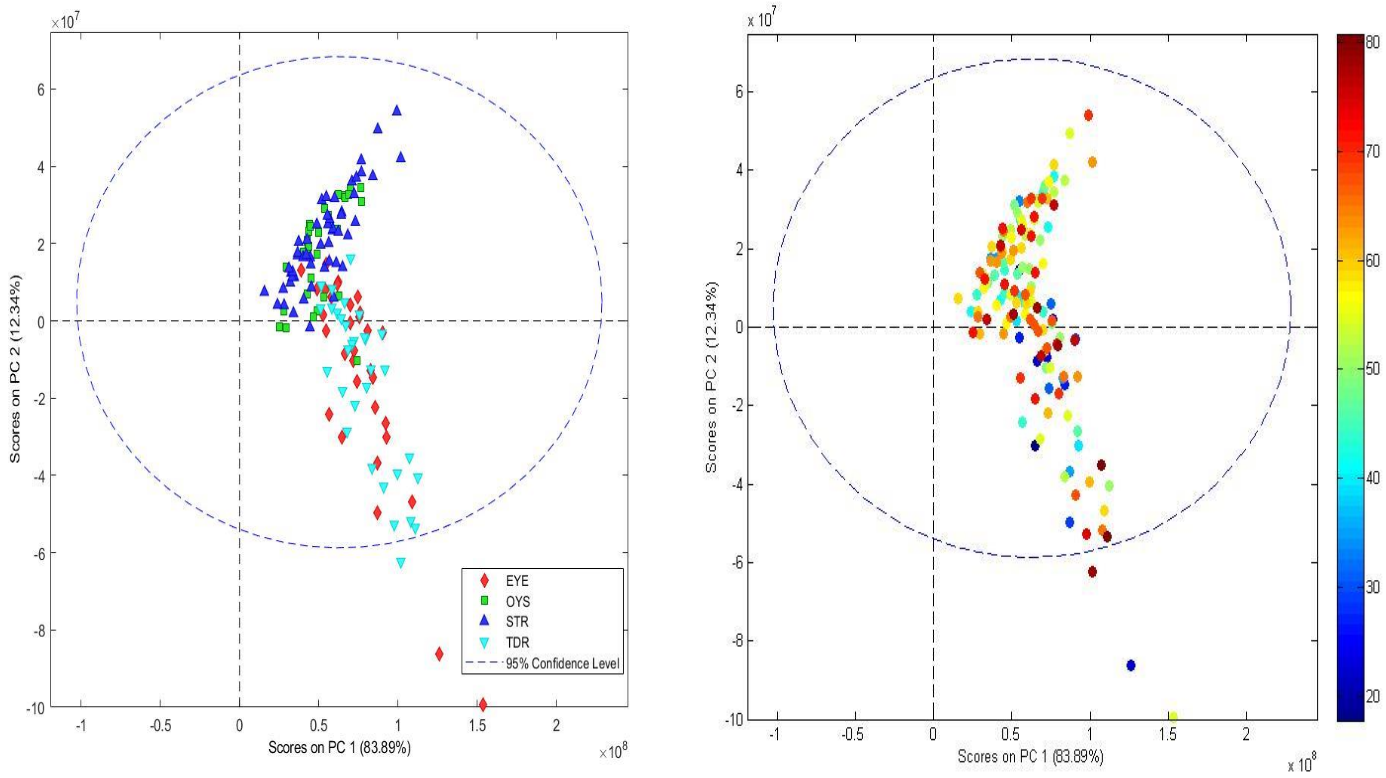
PCA (Principal Component Analysis) was used to seek the similarities and regularities present in the data. Regression analysis (5 regression methods), including linear (PLS (Partial Least Squares), MLR (Multiple Linear Regression)) and non-linear (SVM (Support Vector Machine), ANN (Artificial Neural Network), Xgboost) analyses, were conducted to evaluate and predict each sensory parameter. Variable Importance in Projection (VIP) was used to extract the valuable ions and reduce the dimensionality of the model. Cross-validation used the “leave one out” approach that tests the repeatability and the overfitting of each regression model.

Two statistical parameters are used in the regression to evaluate the calibration and cross-validation of the model. R-squared and the Root Mean Square Error (RMSE) were used for calibration and cross-validation (R^2 Cal, R^2 CV; RMSEC, RMSECV). A model with higher R^2 and lower RMSE indicates superior performance, and a higher ratio between RMSECV and RMSEC suggests that the model is overfitting. The data processing steps were set up in PLS-Toolbox (Eigenvector Research Inc, Wenatchee, USA) and the MATLAB 2020a environment (MathWorks Inc, MA, USA).

6.3 Results and discussion

6.3.1 MS Data processing solution

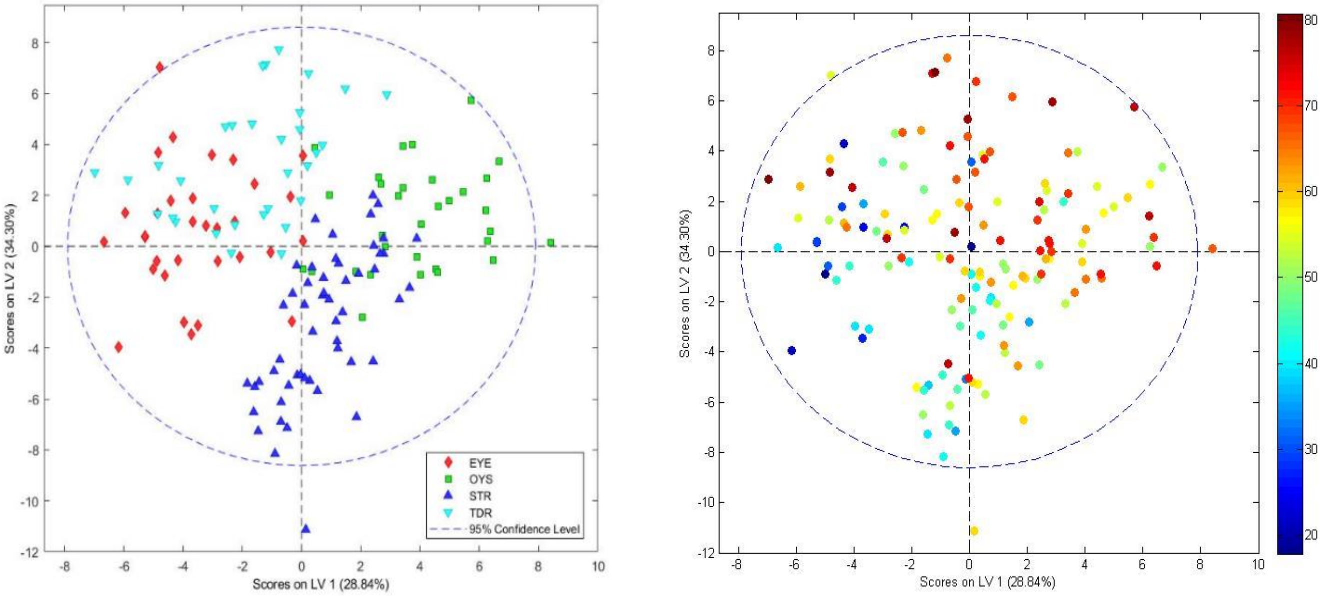
Raw REIMS data (mass range: m/z 50-1200) cannot be classified by muscle types or flavour score by looking at the distribution under the first two principal components (Figure 11). Following the data pre-treatment, one optimal solution assessed sensory score within high R^2, low RMSE, and low ratio between RMSECV and RMSEC after testing 144 attempts from the section of data pre-treatment. The optimal solution under this data processing is: pre-processing (log 10+mean centre) +mass range (m/z 50-1200) + mass bin (0.25) +variable selection (VIP)+PLS regression.



(a) **(b)**

Figure 11 PCA score plot using raw data from mass range m/z 50-1200: (a) Coloured by muscle type; (b) Coloured by flavour score

Muscle types can be distinguished in the first two latent variables of the PLS regression model (Figure 12). R^2 Cal score for each sensory parameter is over 0.95 and all R^2 CV is over 0.80 (Table 15). PLS regression yielded the best performance of the 5 regression methods, which indicates a linear trend connecting the REIMS data and sensory parameters.



(a) **(b)**

Figure 12 The score plot of the VIP-PLS using determined data processing solution: (a) Coloured by muscle type; (b) Coloured by flavour score

Table 15 Regression results using data pre-treatment strategy +VIP-PLS

Sensory parameter	R^2 Cal	RMSEC	R^2 CV	RMSECV
Flavour	0.98	1.95	0.82	6.52
Juicy	0.98	1.98	0.83	6.74
Tender	0.98	2.72	0.81	8.7
O/all like	0.99	1.84	0.83	7.44
Satisfaction	0.97	0.11	0.82	0.27
MQ4	0.99	2.05	0.81	7.39

6.3.2 Interpretation of selected variables

Different VIP-PLS model targeting a single sensory parameter has their selected variables from VIP selection individually, the same arisen variables were gathered for ion interpretation. In total, 260 variables which contain 6% of overall variables show the importance of influencing all the sensory parameters (Table 16).

Table 16 Number of selected variables after VIP selection

Sensory parameter	Number of selected variables	Percentage of overall variables	Number of variables appear in all regression models
Flavour	738	17%	
Juicy	738	17%	
Tender	535	12%	
O/all like	378	9%	
Satisfaction	590	13%	260
MQ4	738	17%	

Cross referencing to the LIPID MAP Structure Database (LMSD) and allowing for a mass tolerance of +/- 0.1 m/z, 95 tentative ions were selected from 260 variables. The distribution of the selected ions under different m/z ranges (Figure 13). These 95 “real” ions were grouped into 6 lipid subgroups: fatty acid [FA], phosphatidic acid [PA], phosphatidylethanolamine [PE], phosphatidylinositol [PI], diacylglyceride [DG], and triacylglyceride [TG]. Less ions appeared below m/z 600, and most of the ions appeared above m/z 600. This indicates that the phospholipid and TG species influence the eating quality, and the linear connection between the sensory parameter and ions is more related to the ions belonging to the phospholipid and TG species.

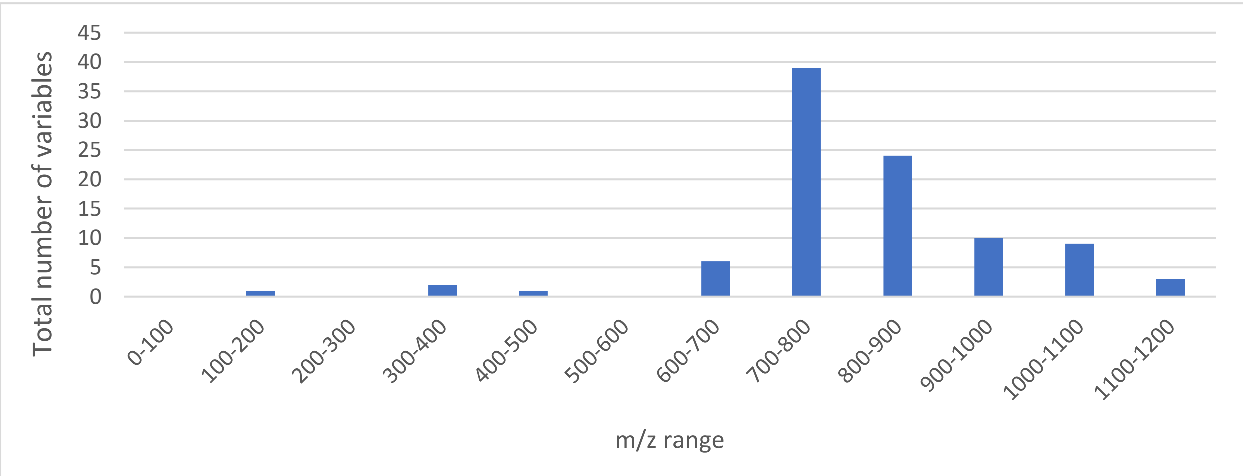


Figure 13 Distribution of selected ions in the different mass ranges

6.4 Conclusion

This study demonstrates the potential of REIMS analysis on raw beef coupled with advanced chemometric modelling to predict the sensory parameters of cooked meat. The REIMS data analysis revealed that the phospholipid and TG are the two main lipid species within the regression model linking lipidomic data and sensory scores. Within the influential MS ions featured in the model, a key subset of 95 that were identified through LMSD, showed the capacity to influence the predictability of the model, either positively or negatively. Future research includes establishing each of the 95 ion's contributions to model success as well as performing classifications instead of only regression, i.e., quantitative predictions. Striding towards a more robust validation of the model, the entire sample set will be split into a calibration series and an independent validation set to conduct the prediction of sensory parameters, which will test the performance of REIMS for a wider range of user environments. Assessment of REIMS analysis on cooked beef samples would also be beneficial to reinforce the robustness of the modelling work. Further work will also focus on only one or two of the critical sensory parameters, especially those with molecular links to specific lipid groups in the beef and investigate the fate of these molecules after cooking, going further into the flavour pre-cursor approach.

7 Industry Engagement

7.1 Communication events and activities

A key element of the BeefQ project has been engaging with industry stakeholders and beef supply chain members to not only share the results from BeefQ activities, but to inform about beef eating quality prediction, how it is conducted, how it can be influenced and the potential benefits the system can provide in terms of delivering a quality product to consumers. To this end, a wide range of engagement events were conducted – these are summarised in Table 17 below and outlined in more detail in Appendix 5. Many of the events that we planned to be in person had to be conducted online due to COVID restrictions at the time, however high numbers of stakeholders were still able to be engaged (Appendix 5).

Table 17 Summary of BeefQ Engagement events

Event Type	No. of Events	Audience
On Farm	9	Producers, advisors
Industry	15	Broader industry stakeholders e.g. farming unions, farming press, processors, food industry, farmers, breed societies, levy bodies etc.
Education	7	Further and Higher Education students and staff

As well as the live events described above, BeefQ produced a series of short videos, targeted mainly towards farmers and the food sector, which outlined how eating quality prediction is conducted, how eating quality can be influenced at the farm level and how eating quality prediction could be implemented in practice, using the Celtica Foods Ltd case study (Section 8) as an example. The videos are available to view through the BeefQ website and the BeefQ YouTube Channel (links in Table 18).

Table 18 Informational videos produced by BeefQ

Videos Produced	**Web links to view**
BeefQ Project	
Video to introduce the project	(808) BeefQ Project Intro - YouTube
BeefQ Farming Connect Demonstration Farm Network Video Series (Summer 2021)	
The impact of genetics on eating quality	(808) The impact of genetics on eating quality (5th July 2021) - YouTube
The impact of health on eating quality	(808) The impact of health on eating quality (12th July 2021) - YouTube
The impact of transport and handling	(808) The Impact of Transport and Handling on Eating Quality (19 July 2021) - YouTube

Extended Beef Video	(808) Extended BeefQ Video (July 2021) - YouTube
BeefQ Project and Celtica Meats Ltd	
Piloting a farm to fork approach to improve the eating quality and consistency of UK beef	(808) BeefQ - A farm to fork approach to consistent beef eating quality - YouTube

22 BeefQ newsletters and 7 press releases have been produced by BeefQ and these are available to view on the BeefQ website (www.beefq.wales). The project has also been regularly updating followers on Twitter (@BeefQWales).

7.2 Stakeholder Survey

An online survey was conducted by the BeefQ project to gauge industry opinion on beef eating quality (EQ), current and potential future carcase valuation systems. The survey was conducted in Welsh and English between 24th January and 12th April 2021. A total of 165 responses were collected, 25 in Welsh and the remainder in English. The majority of respondents were based in Wales and England and 34% of them were farmers.

Overall, respondents felt consumers were confident in the eating quality of Welsh beef, however, a quarter of them, including a quarter of farmer respondents, felt that consumers were not confident in the eating quality of Welsh beef. This suggests a proportion of those involved in the beef supply chain believe there is room to improve the beef eating experience for consumers.

The majority of those directly involved in the production and processing of beef were of the opinion that the beef industry needs to evolve from the current EUROP beef valuation system and that there is an industry wide need to introduce a system of assessment and reward for beef eating quality. Views on how such a system should be implemented were more varied, with an extension to the current EUROP grading system being only slightly favoured over a replacement to the EUROP system.

There was a preference for an eating quality assessment and reward system to be implemented at a UK national level, either by the levy bodies or an independent organisation. As to who would administer and fund the administration of an eating quality assessment and reward system, the levy bodies the most popular choice, or alternatively, administered by an independent organisation and funded by the levy bodies.

The main concerns with respect to barriers to implementation of an eating quality assessment and reward system related to fear of change across the industry and supply chain issues such as lack of cooperation, fairness of cost/benefit within the supply chain and general lack of leadership to take change forward in the UK beef industry. Benefits highlighted included increased sales, improved value within the supply chain and reduced wastage through producing animals that meet consumers requirements.

Full results from the survey can be found in Nicholas-Davies (2021).

7.3 The BeefQ Stakeholder Group and Key Informant Interviews

At the outset of the BeefQ project a BeefQ Stakeholder Group was established and representatives invited from a broad range of stakeholder organisations including the Farming Union of Wales (FUW), NFU Cymru, Young Farmers Cymru, Association of Independent Meat Processors (AIMS), British Meat Processors Association (BMPA), Welsh Government, Institute of Meat, AHDB, Stabiliser Cattle Group and the Royal Smithfield Club. This group met with the BeefQ Management Group five times during the BeefQ project and their roles included, but were not limited to:

- Facilitating and promoting broader industry engagement with BeefQ activities.
- Attending annual project progress meetings.
- Facilitating connections with other projects in this space.
- Facilitating consistent meat-eating quality messages going out to industry.
- Actively engaging in developing the industry strategy for taking the carcase eating quality grading system forward post BeefQ.
- Continuing to generate discussion on how to improve meat eating quality.

This group have also played a key role as "critical friends" to the project – providing feedback on activities conducted and those planned. Most importantly they have been involved in the development and ratification of the recommendations of the BeefQ project.

Where more detailed insight was required from specific stakeholders, semi-structured key informant interviews were conducted. Five interviews were conducted during the project, 4 with beef processors and 1 with a government representative. These interviews focussed on the practical implications of implementing an eating quality system in the UK, looking particularly at the barriers and enablers to doing so. To preserve the anonymity of the interviewees, these interviews are not reported separately but rather feed into the final recommendations of the project.

8 Celtica Case Study

One of the outcomes of the industry wide survey on eating quality conducted by BeefQ in 2021 (see Section 7.2 below) was the lack of clarity regarding how an eating quality system might be implemented and who will take a lead to implement change in the eating quality space. These thoughts were further iterated in conversations with processors when they were questioned how a system like this could be implemented in practice (Section 7.3).

To address some of these concerns, an eating quality grading pilot was implemented with BeefQ project partner Celtica Foods Ltd. This pilot involved the eating quality grading of carcasses and consideration of the costs/practicalities of implementing the grading process.

8.1 Celtica eating quality variables

Data, including UNECE carcase EQ assessments, EUROP classification and cattle information such as passport age and breed were collected from 296 cattle on 9 kill dates between November 2021 and October 2022. The chiller assessment was conducted by Alix Neveu, an accredited grader, initially at the Euro Farm Wales abattoir and then at the Celtica Foods Ltd processing site.

In total, 29 different cattle breed descriptions, the majority representing cross breed combinations, were identified in the sample of 296 cattle and this illustrates the wide range that exists across cattle supply. However, 77% are represented by 6 main breed descriptions (Table 19). These 6 by themselves represent British and European breed types and most likely crosses over dairy breeds creating a significant number of combinations with potential to interact with carcase yield and eating quality.

Table 19 Celtica breed distribution

Breed	**Number**	**%**
Limousin Cross	71	24%
British Blue Cross	55	19%
Hereford Cross	33	11%
Charolais Cross	31	10%
Aberdeen Angus Cross	26	9%
Simmental Cross	12	4%
Other (23 breeds/crosses)	68	23%

Within the population of cattle assessed, only 12% were purely dairy breed type but it is assumed that a sizable additional number may be from dairy breed dams. Table 20 shows a majority (63%) were heifers, a similar pattern to the BeefQ survey conducted in 2018.

Table 20 Celtica breed type distribution

	Heifer	**Steer**	**Total**
Beef	187	74	261
Dairy	17	18	35
Total	204	92	296

Table 21 provides summary statistics of carcase weight (kg) by sex for the Celtica collections. The steers were slightly heavier than the heifers and the dairy steers were lighter than the beef steers. Heifers were represented at both extremes of carcase weight and exhibited a much larger distribution than steers, possibly reflecting the greater numbers or a very broad description of heifer in relation to age, breed type or finish.

Table 21 Celtica carcase weight (kg) x sex

	Heifer (N=204)	Steer (N=92)	Overall (N=296)
Carcase weight (kg)			
Mean [SD]	311 (33.8)	322 (29.6)	314 (32.9)
Median [Min,Max]	311 [228,401]	320 [233,382]	314 [228,401]

Table 22 presents summary statistics for Ossification (Uoss) and Animal age (Days) by sex. The scoring of ossification (or maturity) provides a scale for the assessment of physiological age of a bovine animal. Measurements are recorded in increments of 10 with the lowest being 100 and the highest being 590. The mean ossification and age is greater for the heifers, with the heifer ossification more extreme than in the steers. Age is also more widely distributed in the heifers, but less extreme than for ossification.

Table 22 Celtica ossification (Uoss) and animal age (days) by sex

	Heifer (N=204)	Steer (N=92)	Overall (N=296)
Uoss			
Mean (SD)	206 (43.4)	152 (22.9)	189 (45.5)
Median [Min,Max]	190 [140, 400]	140 [120,230]	190 [120, 400]
Days			
Mean (SD)	876 (211)	861 (187)	871 (204)
Median [Min,Max]	822 [395, 1400]	828 [487, 1420]	822 [395, 1420]

Figure 14 Celtica ossification score by age (days) x sexdisplays the relationship of age (days) relative to ossification score with the heifers including virtually all ossification scores beyond 200, in part explained by the higher age distribution but also likely influenced by hormonal interaction. While the average age for both heifers and steers was 28 months the steers had lower ossification on average (150 against 200 for heifers). The previous BeefQ cattle survey (Section 4) showed a similar large sex effect on ossification development across the cattle population. Compared to the previous survey, Celtica cattle are approximately 80 days older at slaughter, and this is reflected in the slightly higher ossification scores observed. This higher ossification scores (which tends to have a negative impact on EQ), is offset by higher marbling scores (see below) in the Celtica cattle (a positive eating quality factor).

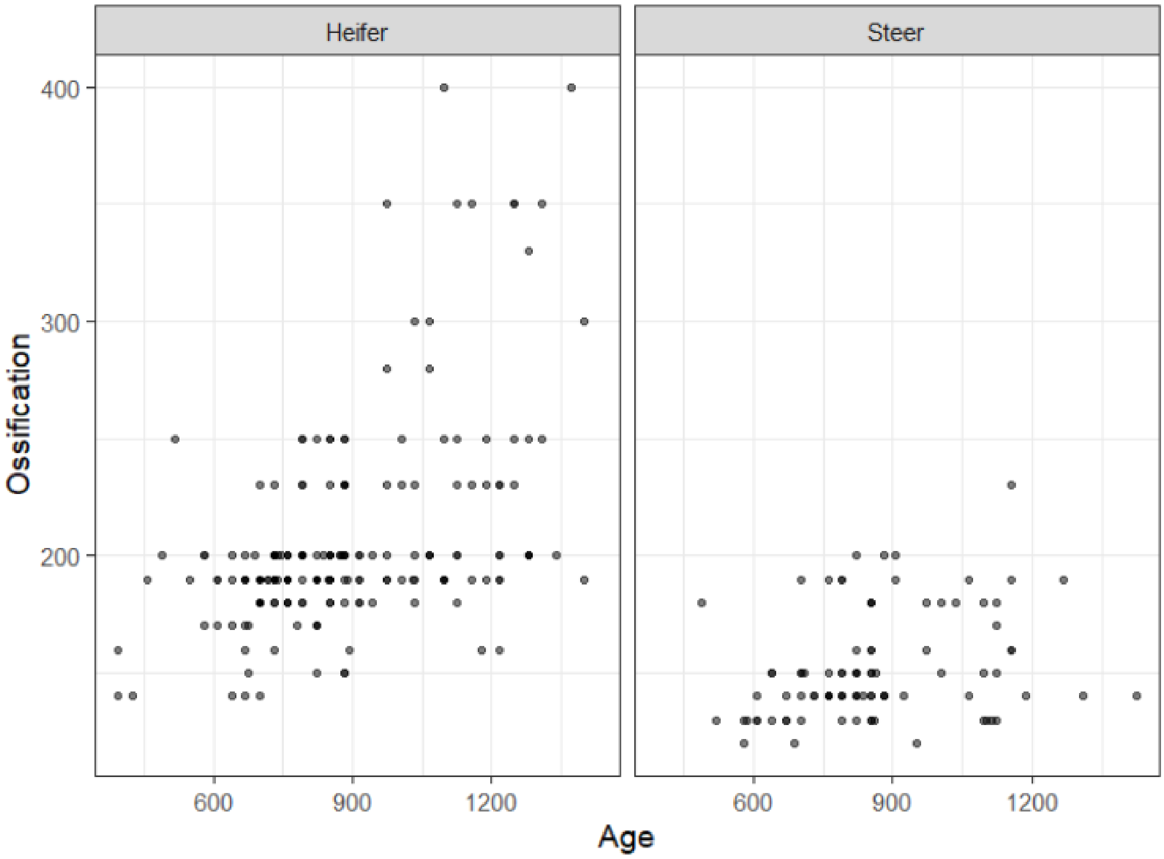


Figure 14 Celtica ossification score by age (days) x sex

Hump height relative to carcase weight (Figure 15 Celtica hump height (cm) x weight within sex categories) is known to be influenced by several factors including breed (with Bos-indicus cattle extreme), hormonal implants, male sex hormone and heavy muscling. A bull effect would be expected and was shown in the BeefQ carcase survey data (Section 4) however, heavier muscled European breeds may also exhibit greater hump. In other Meat Standards Australia (MSA) studies hump in relation to carcase weight has been found useful within eating quality prediction. As Bos-indicus and hormone treatment are common in the MSA data, but not present in the UK, the use of hump:carcase weight in the BeefQ population requires additional analysis to determine if it remains a useful prediction input for the Celtica pilot.

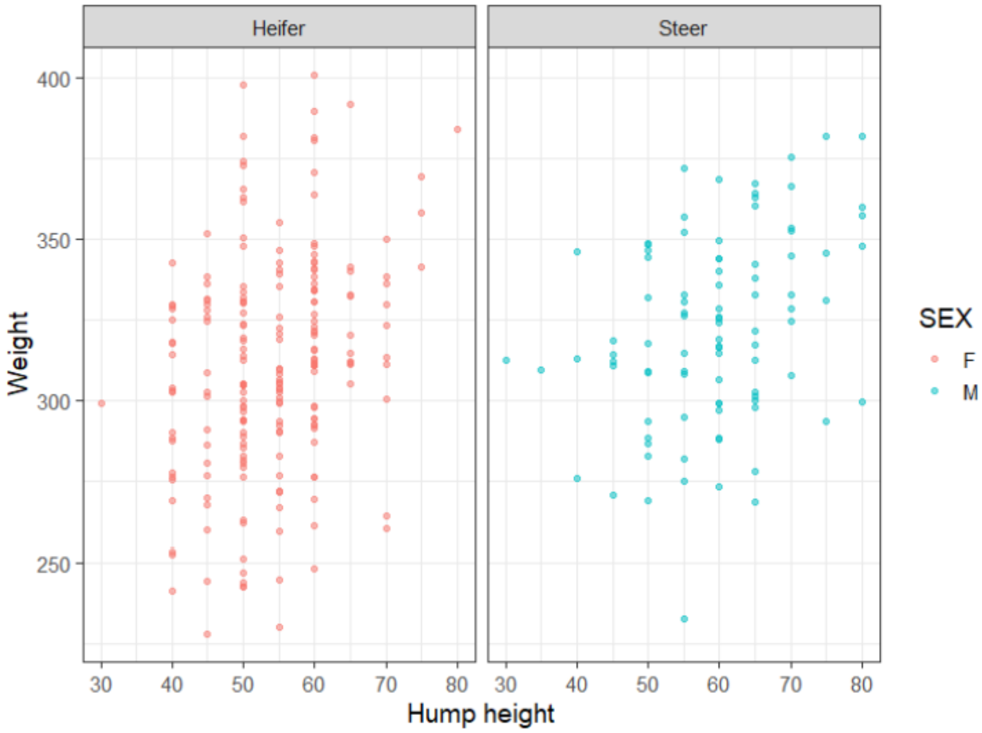


Figure 15 Celtica hump height (cm) x weight within sex categories

Rib fat depth at the 10th rib quartering site was recorded. In Australia, a minimum of 3mm is required for a carcase to be MSA graded, primarily to reduce internal muscle temperature variation (leading to “two toning” during chilling). The rib fat depth is also taken into account in the eating quality predictive model in conjunction with marbling score.

Table 23 shows a wide distribution within the two sex categories. Within the overall population of cattle at Celtica, 19 cattle are below 3mm rib fat, which means that 6% of carcasses would be out of the MSA Eating quality grading specifications.

Table 23 Celtica rib fat (mm) distribution within cattle type

	Heifer (N=204)	**Steer (N=92)**	**Overall (N=296)**
Rib Fat (mm)			
Mean (SD)	9.75 (5.00)	7.50 (4.38)	9.05 (4.92)
Median [Min,Max]	9.50 [0, 36.0]	7.00 [0, 28.0]	8.00 [0, 36.0]

Figure 16 displays the rib fat depth across EUROP fat classes within the sex categories illustrating reasonable correlation with EUROP fat score. However, the correlation tested between the rib fat depth and the European fat class is 0.58 which is not significant, therefore EUROP fat class is not a suitable substitute variable for rib fat depth in eating quality prediction.

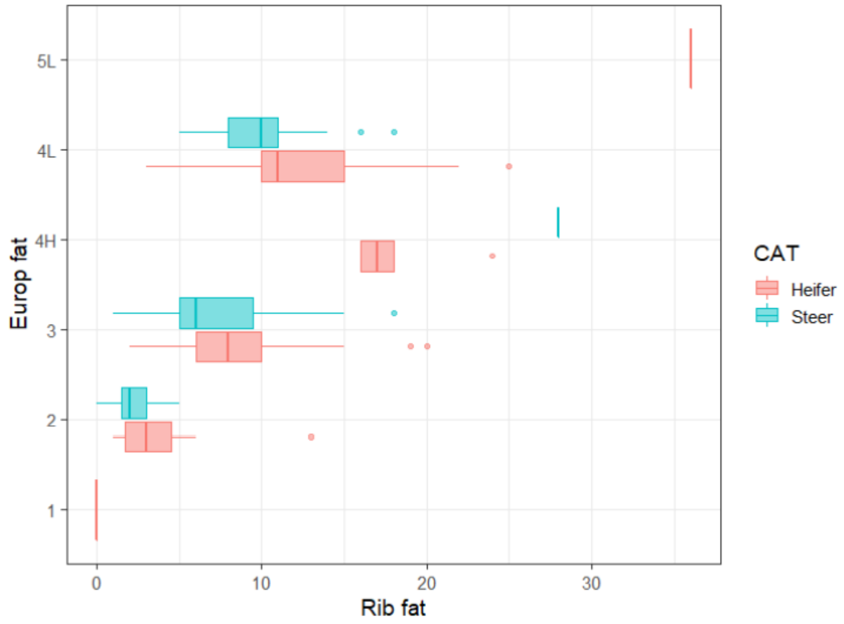


Figure 16 Celtica distribution of rib fat (mm) within sex by EUROP fat class

The distribution of marbling scores is presented in Table 24 and further illustrated in Figure 17. Both steers (M) and heifers (F) encompass a considerable and overlapping range of marbling values with a wider distribution for the heifers including a number of very high values above those recorded for the steer population. These outlier high values were recorded within the beef bred heifers although in general the dairy bred heifers were more different to their steer counterparts than the beef breeds.

Table 24 Celtica marbling score (UMB) distribution by sex

	Heifer (N=204)	Steer (N=92)	Overall (N=296)
UMB			
Mean (SD)	335 (90.8)	318 (76.0)	330 (86.7)
Median [Min,Max]	340 [130, 680]	335 [140, 490]	340 [130, 680]

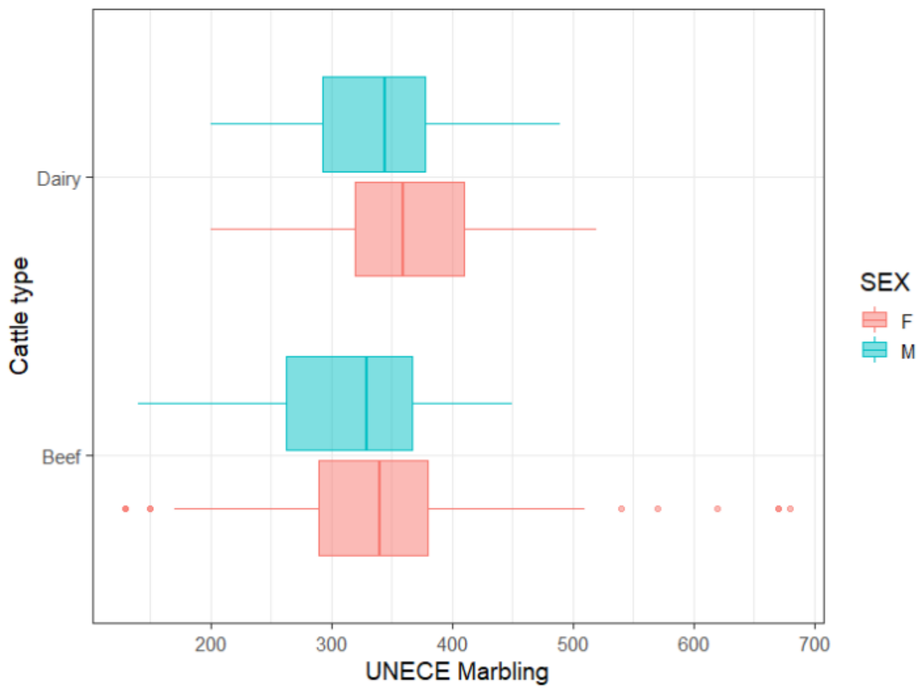


Figure 17 Celtica distribution of marbling score (UNECE marbling) within cattle type and sex

The marbling observation distribution is similar but somewhat higher than the BeefQ survey population where the marbling score average was closer to 300 depending on the season (Figure 1).

Figure 18 displays the ossification score related to the marbling score. The red ring represents grouping for a potential entry level brand where lower marbling and higher ossification align. It is seen that the high outlier marbling values noted in Figure 17 relate to more mature beef females. The blue ring represents suitable relationships for a premium brand related to eating quality. The cut offs could be adjusted to align supply with the proportion and quality level desired within alternative brand categories with commensurate the price differentials.

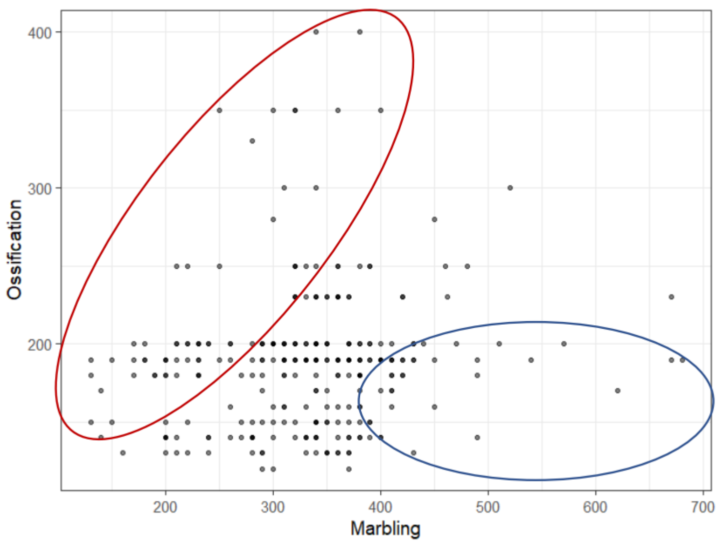


Figure 18 Celtica distribution of ossification and marbling scores

8.2 Celtica eating quality index score

The prediction model approach that will support the Celtica program will group individual cuts within pre-determined eating quality-based settings that support alternative brands for marketing (e.g. good every day, better than every day and premium). This will provide very clear and valuable knowledge to Celtica customers who will be able to select brands that provide a best fit to their price by occasion value points (see Section 9.4 for further detail).

As individual cut relationships differ within each carcase, however, the mix of brand/quality will vary across each carcase and its' source animal.

To provide a simple "animal value rating" an index that in effect weights individual cut weight by brand is proposed. Table 25 provides an indicative example related to a standard cut yield with the percentage of each individual muscle weight, relative to total meat yield, multiplied by the eating quality score for that muscle after assigning a standard cooking method to each.

The Index and associated grading inputs including carcase weight, sex, fat depth, marbling, ossification and pH could be provided as valuable "Feedback" to supplying farmers to enable animal assessment and to identify changes that could increase Index and carcase value to Celtica. Examples include use of a higher marbling sire, reduction in ossification by reducing age at slaughter, reducing stress to avoid high pH or increasing carcase weight at constant age by adjusting feed programs.

The basis for this Index calculation must be further refined as the branding strategy and value relationships are developed. If yields are sufficiently correlated with EUROP muscle and fat scores, or a more refined yield estimate, the Index could be developed further into a true carcase value estimate reflecting both yield and eating quality.

In turn after evaluation of the supply and value differentials a transparent Value Based Pricing (VBP) structure could be trialled as a prospective livestock payment system. In principle this is a highly beneficial approach that could accurately align farmer payment with factory value derived from an accurate consumer driven value.

Table 25 Celtica indicative carcase Eating Quality Index score

	Heifer (N=204)	**Steer (N=92)**	**Overall (N=296)**
EQ Index			
Mean (SD)	57.9 (2.00)	59.7 (1.92)	58.5 (2.13)
Median [Min,Max]	57.9 [52.8, 64.7]	59.8 [52.6, 63.7]	58.6 [52.6, 64.7]

Figure 19 provides an indication of a possible (given the Index applied for this example is indicative only and requires specific Celtica based development) Index distribution for the surveyed Celtica cattle population. A wide 12-point range of index scores is predicted within heifer and steer categories providing considerable potential to encourage and facilitate a more consistent higher value cattle supply

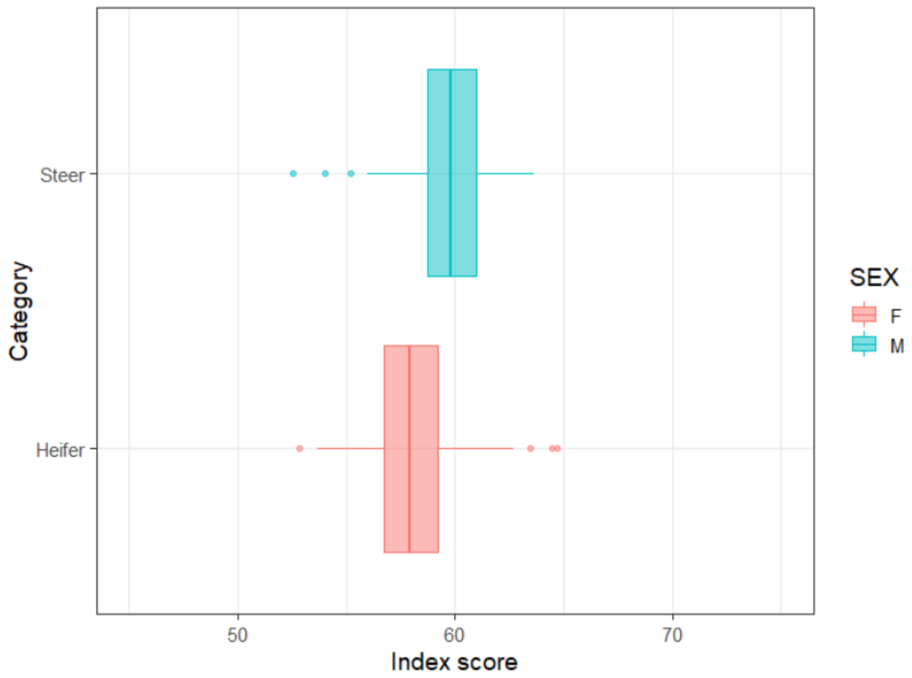


Figure 19 Celtica distribution of an indicative eating quality index within sex category

In Australia, an MSA index score is communicated to all cattle suppliers through mandatory individual animal Feedback reports from the slaughterhouses. This system is widely used to guide future management and breeding decisions as it is closely related to pricing structures.

8.3 Costs to implement EQ grading at Celtica

Table 26 below summarises the costs associated with implementing the eating quality grading pilot at Celtica, more detail on the costs incurred are outlined in the sections below.

8.3.1 Grader Training

One employee of Celtica is undergoing training in eating quality (EQ) grading. This employee has been undertaking practical chiller assessment training alongside a qualified grader trainer who is collecting the data for the case study. The Celtica employee will in due course complete the training course requirement outlined below. An OsCap machine has been leased by Celtica to assist with this training. Staff costs in terms of time spent training to become a grader are not included in Table 26 but should be considered.

More detail on the training process for graders is outlined in Section 9.1

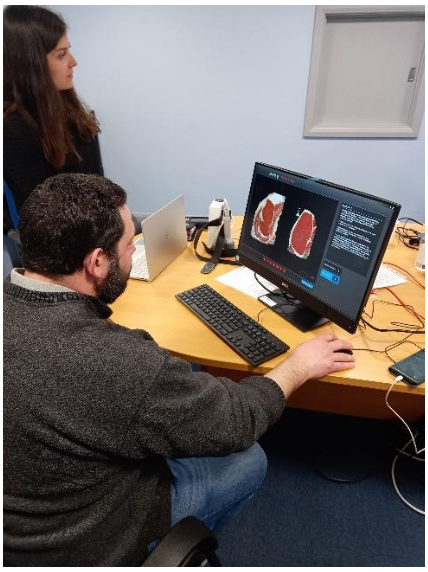


Image 2 OsCap machine being used for EQ grader training at Celtica

8.3.2 Grading Standards

To maintain integrity and data compatibility within the IMR3GF DATAbank the IMR3GF Chiller Assessment Standards may only be used by accredited personnel who have successfully completed an IMR3GF chiller assessment course and are current at the time of assessment requiring correlation on the OsCap system within the prior 8 weeks.

The standards themselves consist of an eye muscle area grid, fat and muscle colour chips, marbling and ossification cards and a torch, battery pack and charger. Additional equipment includes a pH/temperature meter for measuring carcase pH decline in the abattoir post slaughter.

More detail on the grading standards and process can be found in Section 9.1

Image 3 Clockwise from top left, pH/temperature meter, ossification standard cards, torch pack and fat/meat colour chips, meat colour chips.

8.3.3 Databank access

For the purposes of the Celtica case study there was no charge to access the IMR3GF DATAbank to facilitate eating quality prediction as this is a research case study and part of the BeefQ project which has contributed data to the DATAbank. However, if access was required for commercial EQ prediction, then a charge of approximately £0.90/head would be incurred, this is included in the indicative costs in Table 26.

More details on accessing the IMR3GF Databank for research and commercial purposes can be found in Sections 9.2 and 9.3.

Table 26 Indicative costs associated with implementing EQ grading in the Celtica case study

Item	Description	Cost
Grader Training	IMR3GF grader training course	£3050
	OsCap machine delivery and set up	£1050
	OsCap lease (£350/month for 12 months)	£4200
	Qualified grader training input – 0.5 days @ £450/day per grading session (9 kill dates)	£2025
Carcase EQ Grading	0.5 days @ £450/day x 9 kill dates (averaging 33 head/kill date)	£2025
Grading Standards	IMR3GF standard equipment: Eye muscle area grid, fat and muscle colour chips, marbling standard, ossification standard, torch, battery and charger.	£530
	pH/temperature meter	£650
DATAbank access	For EQ prediction – 296 cattle @ £0.90/head	£267
Total		£11,772

8.4 Celtica case study conclusions

The Celtica case study has not only provided detailed data on the range and eating quality potential of cattle sourced by the company but has also provided extremely useful insights into the practicalities and costs associated with implementing eating quality prediction in the business. Moving forward after the BeefQ project, Celtica intend to continue EQ grading cattle until at least March 2023 during which time they will ensure one member of staff becomes fully qualified to EQ grade cattle. This will provide them with in house capacity to continue EQ grading long term with the aims being to provide feedback to producers on how eating quality consistency can be improved, implement practices in product processing that can improve the eating quality of individual cuts, and ultimately offer eating quality differentiated project to its customers.

9 Development of further BeefQ activity to deliver Eating Quality grading

The steps required to develop an Eating Quality Grading System in Wales are briefly presented below.

9.1 Chiller Assessment Training using UNECE Standards

Consistent high-quality data is the critical starting point to ensure accurate product and trait description, to develop consistency in eating quality predictions and accurate grade application. The lead role in ensuring data accuracy rests with the International Meat Research 3G Foundation (IMR3GF). The IMR3GF is a collaborative, independent, not-for-profit foundation in the eating quality research field. It is linked to the United Nations Economic Commission for Europe Specialized Section on Meat.

The 3G Foundation delivers a Chiller Assessment training course (Figure 20 and see details on 3G Foundation website page Training). The scientific background to eating quality assessment component is currently delivered by Dr Grzegorz Pogorzelski (Poland) and Dr Rod Polkinghorne (Australia). The Australian Beef Carcase Assessment System (ABCAS) and practical sessions are conducted by our trainer, Dr Grzegorz Pogorzelski and Alix Neveu (France). A training course lasts 8 days and should be conducted in a slaughterhouse or processing plant where the trainees can assess a minimum of 60 carcasses per day. The current cost of a Chiller Assessment training course is £3,050 per trainee for a minimum of 6 trainees.

Once the Chiller Assessors successfully complete training they are accredited to assess carcasses for different characteristics for research data collection or for commercial use. Individual UNECE standards can be beneficial for trading, for example, to define levels of marbling, meat colour or pH.

To retain currency accredited Chiller Assessors need to access OsCap every 8 weeks and pass a correlation. The machines are leased through the IMR3GF with the current charge £350 per month. The institution or company where the Chiller Assessor belongs is able to purchase a set of chips and torch for each accredited Chiller Assessor for £530 per set. The IMR3GF is currently working with AUS-MEAT to enable on-line correlation without the need for the leased OsCap hardware.

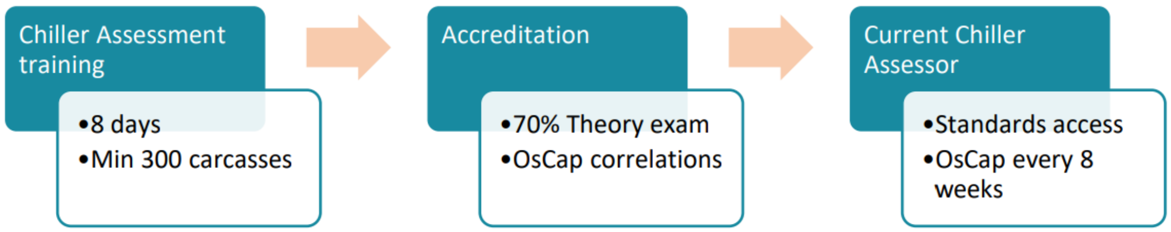


Figure 20 Summary of the steps to become a current 3G Chiller Assessor.

9.2 DATAbank research & commercial agreements

Two levels of license are provided by the IMR3GF; A class 1 commercial level and a class 2 research license. Both require identical chiller assessment accuracy and correlation but differ in the need for external audit under a commercial license.

Once a company has trained a Chiller Assessor, who stays current on OsCap, the data collected can be stored in the cloud-based DATAbank hosted by the Foundation. The DATAbank is a collaborative structure created by a group of participating countries with standardised Eating Quality datasets who wish to collaborate to strengthen the analysis baselines through expanded data.

Each participating country or member has a secure dataset "deposit box" within DATAbank from which, if desired, they can share data to their advantage. The data is owned by the participating country or member and is only shared when mutually agreed. The aim is to provide capacity to maximise value through pooled data & collaboration (Figure 21).

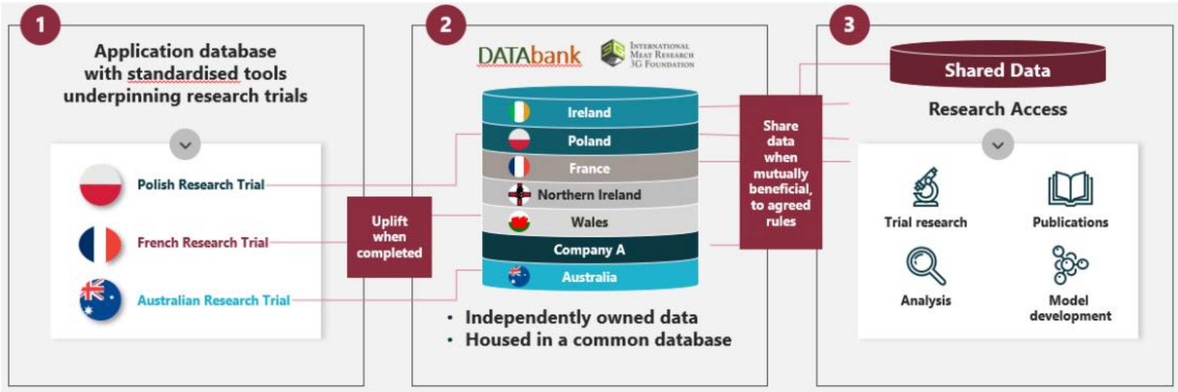


Figure 21 DATAbank organisation

Individual UNECE standards such as marbling can be used alone as a component of carcase descriptions, but far greater consumer relevance and commercial value can be delivered by use of a 3G prediction model that utilises all measurements interactively to predict a consumer eating quality (3G) score (1 to 100) for individual muscle x cook combinations. These scores can be used to segregate product into controlled individual score bands providing consistent consumer outcomes and associated increased value. Current inputs utilised in 3G modelling are displayed below.

Figure 22 displays the result calculated from the transmitted chiller assessment and other required detail to the IMR3GF.

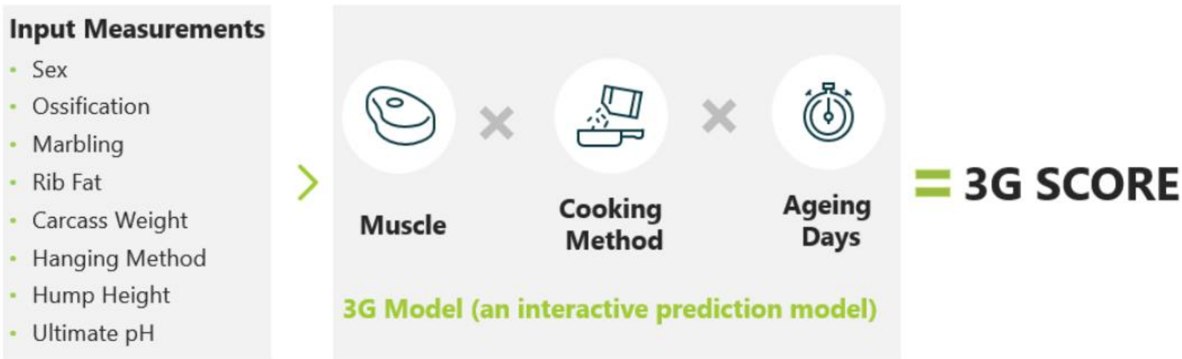


Figure 22 3G calculation score

The 3G score for each muscle (sometimes several within a common cut) is calculated from the inputs as entered by the Chiller Assessor. The prediction model takes these inputs and calculates the combined effect for each muscle. This allows traits such as marbling or ossification to be of greater or lesser importance depending on the cut. Alternative 3G scores are also produced for each cooking method in the model so that a cut may rate higher as a roast than a grill etc. The model estimates the maturation effect, and in some circumstances, retail packaging system, allowing a factory or customer to have a final 3G value that reflects the Eating Quality of each meal sized portion after allowing for all factors from the live animal, processing, cooking and maturation.

Country or company specific models can be developed where sufficient data exists, as in the Australian MSA model. For Wales a more powerful model is currently produced by pooling additional extensive European data that includes additional cook types, muscles and maturation variation with the potential to refine a base model for specific Welsh cattle or consumer populations.

The BeefQ data is currently stored in the DATAbank and its access will be defined. In Wales, an organisation such as HCC could be capturing the data and storing it within the DATAbank making it available for industry and research. Figure 23 shows an example for research data collection.

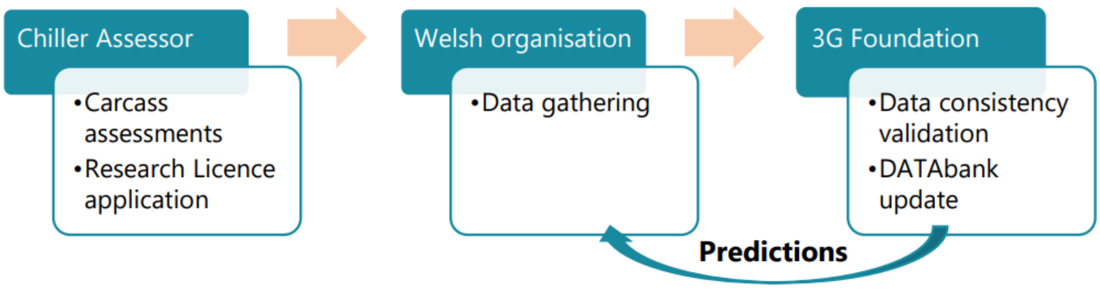


Figure 23 Data collection steps for Research

The 3G score using the European or Welsh predictive model is then returned to the Welsh organisation which would be charged 1€/head. This cost may decrease if the number of carcasses per week exceeds 50 on average for an organization or if greater system throughput reduces the IMR3GF operating cost. As displayed in Figure 24, these scores and "grades" or brands related to score criteria are returned electronically to the grader for application to the now graded carcase.

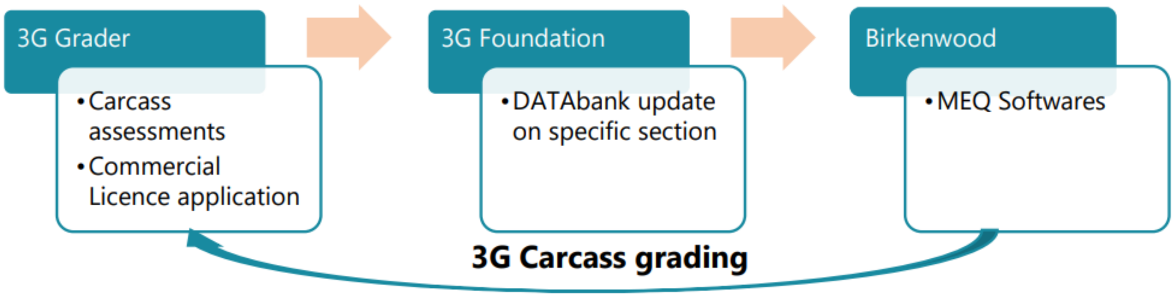


Figure 24 Commercial data collection

The muscle 3G scores can be combined with their relative weight to produce an Index to provide an overall carcase 3G Index. The Index can be between 0 to 100. This can be a very useful tool for cattle producers, akin to a breeding index but reflecting management post birth in addition to genetic merit, to compare cattle supplied to different factories or over time and to relate to sires or management strategies such as alternative feeding regimes.

The Class 2 license for research purposes requires identical competency and accreditation to the Class 1 commercial license but allows more self-assessment. The Class 2 category was created to encourage and enable consistent high quality data collection by researchers while recognising that the non-commercial and relatively small scale of collections made a full Class 1 cost structure a major obstacle to adoption.

The higher-level Class 1 license is required for commercial grading which requires grading processes including grader currency, control of standards and reconciliation of product graded and packed to be covered by internal QA and externally audited. Typically, these requirements would be added within existing BRC or equivalent arrangements. These conditions result in increased cost relative to a Class 2 license but are necessary to ensure trade integrity.

9.3 Commercial implementation of an Eating Quality Grading system

Figure 25 displays each step of an Eating Quality system implementation delivered by Birkenwood within a company and adapted to each factory facility.

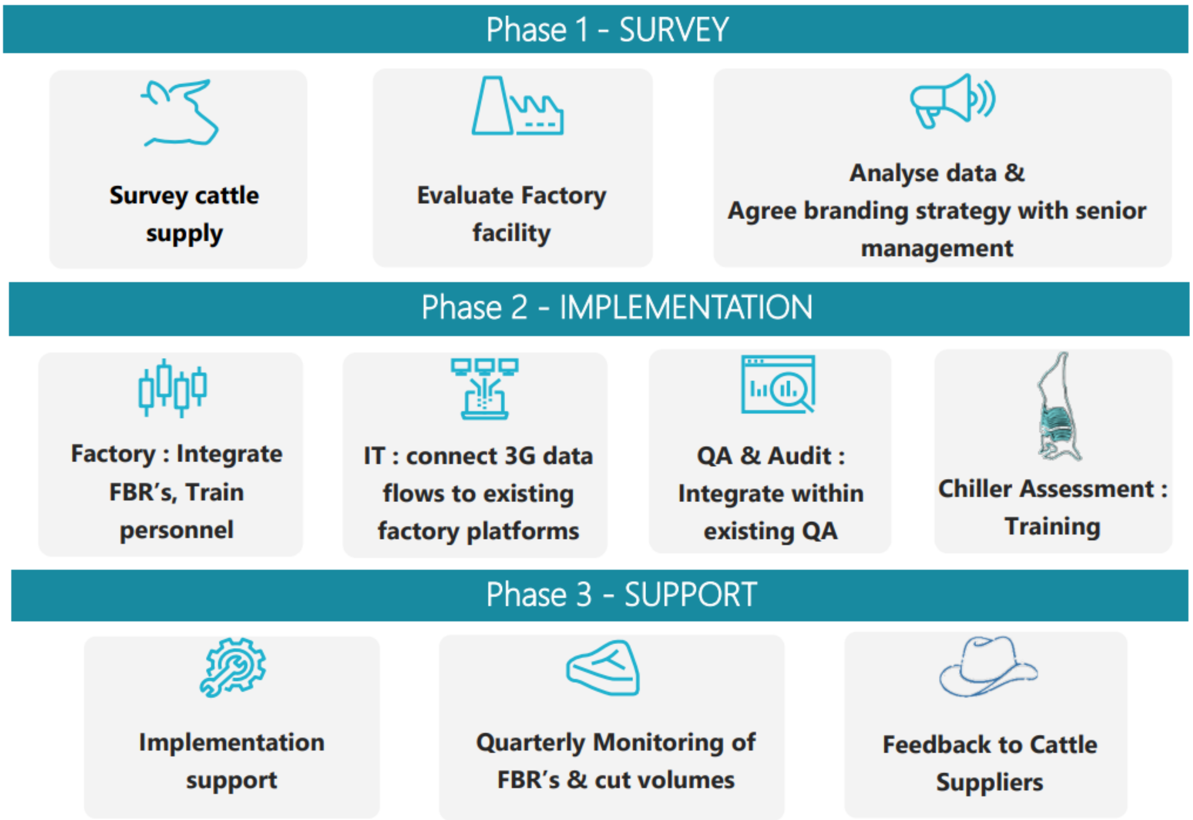


Figure 25 Birkenwood 3G implementation

Please contact the Birkenwood team for further information.

9.4 Tailored grading outcomes

The consumer offer can be simplified to a matrix of desired meal type by occasion. With a high quality and price product offering a solution for a very special occasion under the premium category and an everyday product at much lower price perfect for another occasion. This can allow beef to be as simple to buy as other consumer products by removing the need for expert consumer knowledge and the associated "fear factor" when they are purchasing beef. This provides a solid scientific base to empower beef brands. (Figure 26).

The Occasion		Grill	Roast	Slow Cook	Stir Fry	Shabu shabu	Yakiniku
Premium	3G Score	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

Figure 26 Meal by occasion descriptions

Birkenwood International can be contacted at:

BIRKENWOOD INTERNATIONAL

45 Church Street

Hawthorn

Victoria 3122

Australia

(PH): (61) 410 300 905

https://www.birkenwood.org/

The International Meat Research 3G Foundation website is: https://imr3g.org/about-foundation/

10 Recommendations and Conclusions

The BeefQ project has successfully tested and demonstrated the use of a modified Meat Standards Australia system for predicting eating quality in the project. Due to the pre-competitive nature of the BeefQ project, the required data is now available to both research and commercial organisations to take beef eating quality prediction forward in the UK. Extensive industry engagement throughout the project has indicated that there is an appetite for change to the current system for beef valuation in the UK with more focus on the customer. It is now up to that same industry to drive this change forward in a transparent and cohesive way to ensure the long-term sustainability of the beef industry in Wales and the wider UK.

The following 5 recommendations are made by the BeefQ Project Management Group and ratified by the BeefQ Stakeholder Group as key to moving the beef eating quality agenda forward in the UK after the completion of the BeefQ project.

Recommendation 1 - The EQ prediction tools based on the MSA system have been successfully tested and demonstrated in the BeefQ project

Analysis of the carcase survey and consumer taste testing data collected in BeefQ demonstrates that a modified MSA model can be used to successfully predict the eating quality of the beef graded in the project.

Recommendation 2 - Data collected by the BeefQ project to develop the eating quality prediction model will be held in the DATAbank hosted by the International Meat Research 3G Foundation.

The International Meat Research 3G Foundation (IRM3GF) is a collaborative, independent, not-for-profit international eating quality research platform. The IRM3GF's Databank currently holds eating quality data similar to that collected in BeefQ from a number of countries (e.g. Japan, New Zealand, Australia, Poland, France). There is no fee to store the data in the Databank, and no fee for research access to the data. The Databank works on the principle that the more research projects contribute data, the stronger the eating quality prediction models accessible via IRM3GF. To access the data and prediction models via the IMR3GF for commercial purposes, there is a small fee per head of cattle. The recommendation is that access to the BeefQ data remains in the future for research and commercial purposes.

Recommendation 3 - Communication and dissemination resources will be hosted by Hybu Cig Cymru (HCC) once the BeefQ project has ended.

The beef eating quality pages within the HCC website will be the first point of call for researchers and commercial organisations interested in learning more about beef eating quality and the systems used to predict eating quality. The material (including reports and informational videos) currently hosted on the BeefQ project website (www.beefq.wales) will be transferred to HCC.

Recommendation 4 - Stakeholder feedback indicates that transparent, national, eating quality (EQ) prediction standards are required in order for the industry to move forward.

Transparent standards governing the training and validation of EQ graders, variables used to predict EQ and method of collection, models used to predict EQ and the criteria used to determine categories of eating quality used in marketing of products, are required in order for eating quality prediction to move forward in the UK. Many of the systems required are already in operation in other countries and the BeefQ project has demonstrated a system that works for UK beef and consumers; however, further consumer-based testing is needed to provide more robust prediction (e.g. using additional cooking methods to that used in BeefQ). In terms of developing a payment system for beef carcasses that include an eating quality element it must be noted that the current EUROP system is of value in the processing sector for providing a standard yield measurement and any eating quality standards system should complement rather than replace the valuable attributes of EUROP.

Recommendation 5 - Further research is needed in the UK to take the beef eating quality agenda forward.

Research areas identified include how eating quality fits in with the environmental quality agenda; how selecting for efficient animals affects eating quality; identifying potential trade-offs/synergies between eating quality improvement and performance objectives, more pilots and trialling on eating quality prediction, particularly in the context of larger meat processing businesses, and finally development of a set of standards for eating quality prediction in the UK.

11 Acknowledgements

The BeefQ Management Group would like to gratefully acknowledge the contribution of the many individuals and organisations who have contributed to the project, particularly the meat processing companies that engaged the project and the BeefQ Stakeholder Group. We also acknowledge the funding received from the Welsh Government and the European Agricultural Fund for Rural Development, without which, the project would not have been possible.

12 References

Barlow, R.S., Fitzgerald, A.G., Hughes, J.M., McMillan, K.E., Moore, S.C., Sikes, A.L., Tobin, A.B. and Watkins, P.J. (2021). Rapid Evaporative Ionization Mass Spectrometry: A Review on Its Application to the Red Meat Industry with an Australian Context. Metabolites, [online] 11(3), p.171.

Bonny, S.P.F., Gardner, G.E., Pethick, D.W., Allen, P., Legrand, I., Wierzbicki, J., Farmer, L.J., Polkinghorne, R.J., Hocquette, J.F. (2017) Untrained consumer assessment of the eating quality of European beef: 2. Demographic factors have only minor effects on consumer scores and willingness to pay. Animal,11(8):1399-1411.

Devlin, D. J., Gault, N. F. S., Moss, B. W., Tolland, E., Tollerton, . J., Farmer, L. J.,Gordon, A. W. (2017) Factors affecting eating quality of beef. Advances in Animal Biosciences, 8:s1, pp s2–s5.

Gee, A., Porter, M., Polkinghorne, R. (2005) 'Protocols for the thawing, preparation and serving of beef for MSA trials for five different cooking methods.' (Meat and Livestock Australia: Sydney)

Hybu Cig Cymru (2014) Strategic Action Plan for the Welsh Red Meat Industry 2014-2020. Available at: https://meatpromotion.wales/images/publications/HCC_-_Strategic_Action_Plan_ENGLISH_Final.pdf [Accessed 08/11/22].

Khan, M.I., Jo, C., Tariq, M.R. (2015). Meat flavor precursors and factors influencing flavor precursors—A systematic review. Meat Science, 110, pp.278–284.

Logan, R., Bevan, K. (2014) A Review of the Beef Sector in Wales, Commissioned by Hybu Cig Cymru – Meat Promotion Wales (HCC). Available at: https://meatpromotion.wales/images/publications/A_review_of_the_Beef_Sector_in_Wales.pdf [Accessed 08/11/22]

Nicholas-Davies, P.K. (2021) BeefQ Survey Industry Survey. Beef eating quality, current and potential future carcase evaluation systems. Viandes & Produits Carnés – 22 Novembre 2021. Available at: https://www.viandesetproduitscarnes.com/phocadownload/vpc_vol_37/Vol_3743_BeefQ.pdf [Accessed 8/11/22]

Park, B., Hwang, I., Cho, S., Yoo, Y., Kim, J., Lee, J., Polkinghorne, R., & Thompson, J. (2008). Effect of carcass suspension and cooking method on the palatability of three beef muscles as assessed by Korean and Australian consumers. Animal production science, 48, 1396-1404.

Polkinghorne, R.J. (unpublished) BeefQ Stage 1 Project Report – Carcass Survey. Birkenwood International.

Polkinghorne, R.J., Nishimura, T., Neath, K.N., Watson, R.K. (2011) Japanese consumer categorization of beef into quality grades, based on Meat Standards Australia methodology. Animal Science Journal, 82,325–333.

Robson, K., Birse, N., Chevallier, O. and Elliott, C. (2022). Metabolomic profiling to detect different forms of beef fraud using rapid evaporative ionisation mass spectrometry (REIMS). npj Science of Food, [online] 6(1).

Ruiz-Capillas, C., Herrero, A.M., Pintado, T. and Delgado-Pando, G. (2021). Sensory Analysis and Consumer Research in New Meat Products Development. Foods, 10(2), p.429.

Watson, R., Gee. A., Polkinghorne. R., Porter, M. (2008a). Consumer assessment of eating quality - development of protocols for MSA testing. Australian Journal of Experimental Agriculture,48,1360–1367.

Watson, R., Gee, A., Polkinghorne, R., Porter, M. (2008a) Consumer assessment of eating quality – development of protocols for MSA testing. Australian Journal of Experimental Agriculture, 48,1360–1367. Accessory publication Appendix: MSA sensory testing protocols (csiro.au) [Accessed 8/11/22].

Watson, R., Polkinghorne, R., Thompson, J.M. (2008b). Development of the Meat Standards Australia (MSA) prediction model for beef palatability. Australian Journal of Experimental Agriculture,48,1368–1379.

Zhai, C., Schilling, B., Prenni, J.E., Brooks, J.C., Legako, J.F., Miller, R.K., Hernandez-Sintharakao, M.J., Gifford, C.L., Delmore, R. and Nair, M.N. (2022). Evaluating the ability of rapid evaporative ionization mass spectrometry to differentiate beef palatability based on consumer preference. Journal of Food Science and Technology, 59(10), pp.4134–4140.

Appendix 1 – Location and dates of BeefQ consumer taste testing events.

Date	Test Location
30/09/19	Castell Howell Foods Cross Hands
1/10/19	Dexters Restaurant Carmarthen
3/10/19	Coleg Cambria Lysfasi
7/10/19	Coleg Ceredigion
8/10/19	Whitland RFC
9/10/19	Coleg Pows Newtown
10/11/19	Coleg Sir Gar Pibwrlwyd Carmarthen
13/11/19	Pembrokeshire College
14/11/19	HCC Autumn Conference Builth Wells
18/11/19	Aberystwyth University
19/11/19	Aberystwyth University
9/12/19	Coleg Sir Gar Llandeilo
15/01/20	Reaseheath College Nantwich
22/01/20	Machynlleth RFC
23/01/20	Coleg Meirion Dwyfor Dolgellau
3/02/20	ABP Ellesmere
4/02/20	Colchester Institute
12/02/20	Cardiff and The Vale College
25/02/20	Dolgellau RFC
26/02/20	Coleg Powys Newtown

Appendix 2 – Consumer taste testing Questionnaire

Date: ____________________ Group Name: ___________________________

I.D. Number: ______________ Session Number: ________________________

Thank you for your participation today with our meat tasting

Before you commence please **listen** to the instructions on how to use the scales contained in this questionnaire.

In between each sample please **cleanse** your palate by first taking a sip of diluted apple juice then chew a piece of bread and then take another sip of diluted apple juice.

We are after your opinion and therefore ask that you **do not talk** to anyone else in the room during the research session.

Now just a few questions about yourself, please tick the appropriate box. (All this information is strictly confidential).

1) Demographic data

Please write down the county of the address you normally live at: ______________________

2) Age group (please tick 1 box)

18-19 years	20-25 years	26-30 years	31-39 years	40-60 years	Older than 60 years
☐	☐	☐	☐	☐	☐

3) Gender (please tick 1 box)

Male ☐	Female ☐	Other ☐

4) What is the occupation of the main income earner in your household? (please tick 1 box)

Trades	Profession eg. Teacher	Admin	Farming	Sales/ Service	Manual worker	Home Duties	Student	Other employment	Not employed
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

5) How often do you eat beef? (in any form such as steaks, roasts, stews, casseroles, mince, BBQ, etc., please tick 1 box)

Daily	4-5 times a week	2-3 times a week	Weekly	Fortnightly	Monthly	Never eat
☐	☐	☐	☐	☐	☐	☐

6) How many people normally live in your household? (Adults are aged 18 years and over)

	1	2	3	4	5	6	7	8 or more
Adults	☐	☐	☐	☐	☐	☐	☐	☐
Children	☐	☐	☐	☐	☐	☐	☐	☐

7) Please read the following statements and tick the <u>one statement</u> that applies to you

☐ I enjoy red meat. It's an important part of my diet

☐ I like red meat well enough. It's a regular part of my diet

☐ I do eat some red meat although, truthfully it wouldn't worry me if I didn't

☐ I rarely / never eat red meat

8) When you eat beef, such as steaks, what level of cooking do you prefer? (please tick 1 box)

Blue ☐	Rare ☐	Medium/Rare ☐
Medium ☐	Medium/Well Done ☐	Well Done ☐

9) What level of income best categorises your <u>combined household income</u>? (please tick 1 box)

Less than £25,000 per year	£25,001 to £50,000 per year	£50,001 to £75,000 per year	£75,001 to £100,000 per year	£100,001 to £125,000 per year	£125,001 to £150,000 per year	More than £150,000 per year

..	☐	☐	☐	☐	☐	☐

10) What level of education have you reached? (please tick 1 box indicating the highest education level achieved)

Did not complete secondary school	Completed secondary school	College/ A Levels	University graduate
☐	☐	☐	☐

11) What is your cultural heritage? (please tick 1 box)

Welsh descent	British descent	European descent	Asian descent	Other	Prefer not to say
☐	☐	☐	☐	☐	☐

If other please specify ___________________________

All information collected in this survey is strictly confidential.

Appendix 3 – Consumer testing sample score sheet

PRODUCT:

Tenderness

Not Tender | Very Tender

Juiciness

Not Juicy | Very Juicy

Liking of flavor

Dislike Extremely | Like Extremely

Overall Liking

Dislike Extremely | Like Extremely

Please tick [✔] one of the following to rate the quality of the beef sample you have just eaten. Choose **one** only (you must make a choice).

- Unsatisfactory ☐
- Good everyday quality ☐
- Better than everyday quality ☐
- Premium quality ☐

Appendix 4 – Willingness to pay form included in the consumer testing.

Based on the beef you just consumed: Please mark the line at the price per Kg you believe best reflects the value for each category.

Unsatisfactory Quality

£0/Kg £5/Kg £10/Kg £15/Kg £20/Kg £25/Kg £30/Kg £35/Kg £40/Kg

Good Everyday Quality

£0/Kg £5/Kg £10/Kg £15/Kg £20/Kg £25/Kg £30/Kg £35/Kg £40/Kg

Better than Everyday Quality

£0/Kg £5/Kg £10/Kg £15/Kg £20/Kg £25/Kg £30/Kg £35/Kg £40/Kg

Premium Quality

£0/Kg £5/Kg £10/Kg £15/Kg £20/Kg £25/Kg £30/Kg £35/Kg £40/Kg

Are you the regular purchaser of beef for your family (please tick one box)?

Yes ☐	No ☐

Appendix 5 List of farm based, industry and educational events conducted in BeefQ.

Date	Location	Event	No Participants	Target Audience	Title of Presentation	BeefQ Representative
Farm Events						
06-Jun-19	Cardeeth Farm, Carew, Pembrokeshire	RWAS Pembrokeshire Grassland Event		Farmers		Gareth Evans
06-Jun-19	Maes Tyddyn Isaf, Clawdd Newydd, Ruthin	Farm Connect & BeefQ meeting	c 50 beef farmers	Beef farmers		James Draper
24-Jun-19	Tyddyn Isaf Farm, Ruthin, North Wales	Group Update presentation	ABP Colleagues	ABP Colleague s and key cust accounts	BeefQ Project	James Draper
19-Oct-20	Webinar for AgriSearch/EIT Food "Focus on Farmers"	Focus on Farmers Virtual Farm Walk & discussion - series of beef seminars funded by AgriSearch - 19 October 2020	224 people on webinar plus additional people on Facebook Live	Farmers (82%). Attendees from across UK & Ireland (mostly Northern Ireland)	"Lost on the journey - does eating quality of beef matter?"	James Draper Chair / Nigel Scollen Presenting
27-Jan-21	Webinar organised by Farming Connect	2 BeefQ Webinars for Consultation and Survey - aimed at Food Industry 25.1.21 and Farmers 27.1.21	60	Farmers	BeefQ results and the way forward to improve beef eating quality for the food industry / BeefQ results and the way forward for beef eating quality in the farming industry	Deanna Jones / Pip Nicholas Davies
25-Nov-21	Pantyderi Farm, Pembrokeshire	Farming Connect Demonstration Farm Event	30	Farmers	Update on BeefQ project	Pip Nicholas-Davies,
17-Feb-22	Virtual	NFU Cymru Livestock Board	20	Farmers	Update on BeefQ project	Pip Nicholas-Davies
28-Apr-22	Tyddyn Gwyn Farm, Pwllheli	Farming Connect Demonstration Farm Event 'Bull Beef Finishing'	33	Farmers	Update on BeefQ project and showing of new video	Tim Rowe, Gareth Evans
15-Jun-22	RWAS Show Ground	Innovation and Diversification Wales Event		Farmers	Opportunity to provide an update on the project	Pip Nicholas-Davies
Industry Events						

24-Jul-19	RWAS Show Ground ABP Stand	RWAS	8 Master Butcher Candidates from Bookers, Group Chairman Mark Rogers and James Draper ABP	Master Butchers, Wholesalers	BeefQ Presentation	James Draper (Eleri Price)
13-Sep-19	Hybu Cig Cymru, Head Office, Aberystwyth	Lee Leachman and Stabiliser Groups BeefQ presentations and discussion	Rhys Jones, Elizabeth Swancott (HCC), Iestyn Jones (WLBP), Lee Leachman (Leachman Cattle, USA), Seth Waring, Ursula Tayor, Richard Taylor and Richard Parry (Stabiliser Group)	Discussion	BeefQ project and preliminary data from carcase grading	Deanna Jones, Pip Nicholas-Davies, Gareth Evans, Tim Rowe, James Draper (ABP),
25/26-Nov-19	RWAS Show Ground	RWAS Winter Fair	Visitors to the Wynnstay stand at the show	Industry Stakeholders	None	Gareth Evans
04-Feb-20	ABP Ellesmere	Producer workshop	12	Beef Producers		Deanna Jones
15-Feb-20	Glasgow	QMS Conference		Workers in the Red Meat Industry	Rod mentioned BeefQ as a great example of proactive industry engagement	Rod Polkinghorne
23-Jul-20	Virtual	RWAS	55	Industry Stakeholders	BeefQ - Beef Eating Quality Project Progress and Q&A	Pip Nicholas-Davies, Rod Polkinghorne, Deanna Leven, Nigel Scollan, Eirwen Williams, Tim Rowe, James Draper
04-Dec-20	Virtual	EAAP Conference Session 68 'Collaborative International Research Related to Beef Quality'			BeefQ - Building capacity for beef eating quality assessment in Wales / Pasture feeding effects on a-tocopherol content and lipid oxidation of beef from late maturing bulls	Pip Nicholas-Davies / Sibhe Siphambili

25-Jan-21	Webinar organised by Farming Connect	2 BeefQ Webinars for Consultation and Survey - aimed at Food Industry 25.1.21 and Farmers 27.1.21	20	Food Industry	BeefQ results and the way forward to improve beef eating quality for the food industry / BeefQ results and the way forward for beef eating quality in the farming industry	Deanna Jones / Pip Nicholas Davies
13-Jun-19	ABP Ellesmere	Livestock Procurement	4	Livestock Procurem ent to then speak to Suppliers when on farm	Used the Farming Connect Meeting that Deanna forwarded	James Draper
22-Jul-19	Royal Welsh WAOS Pavilion	BeefQ Presentation and Tasting	40	Farmers, Producers , Agri Colleges, Unions	BeefQ Project	Pip Nicholas-Davies (James Draper, Tim Rowe, Eleri Price, Deanna Leven, Gareth Evans, Eirwen Williams/Sian Tandy, Ffion Scourfield, Nigel Scollen, Rod Polkinghorne)
25/26-May-21	Virtual	United Nations Food Systems Summit (UNFSS)			The Role of the Global Meat Sector in Future Sustainable Food Systems	Pip Nicholas-Davies, Deanna Jones, Rod Polkinghorne, Alix Neveu, Holly Cuthbertson, Tim Rowe
20-Jul-21	Virtual	RWAS		Food Industry / Farmers	How genetics, health and handling can influence beef eating quality from a meat science perspective / a processors view of the impact of poor performance in these areas on animals submitted for slaughter.	Pip Nicholas-Davies / Deanna Jones / Eleri Thomas / Tim Rowe / Eirwen Williams

10-Nov-21	Virtual	Hybu Cig Cymru Annual Conference	48	Food Industry	BeefQ – How could it work in practice? A case study with Celtic Pride.	Pip Nicholas-Davies, Tim Rowe, Nigel Scollan
29/30-Nov-21	RWAS Winter Fair	BeefQ presence on Wynnstay Stand		Food Industry / Farmers		Tim Rowe, Gareth Evans
19-Jul-22	RWAS Showground	Royal Welsh Show		Food Industry	Panel discussion and cookery demonstration	BeefQ Team
Education Setting						
21-Aug-19	Aberystwyth University	Distance Learning Lecture - BeefQ	30 Students	Masters distance learning students	BeefQ Project	Pip Nicholas-Davies
24-Oct-19	Aberystwyth University	Livestock Science module lecture	30 Students	Lecture delivered to 30 undergraduate students	BeefQ Project	Pip Nicholas-Davies
17-Nov-19	Aberystwyth University	Stapledon Society Guest Lecture	80 (mix of students and Stapledon Society Members)	Stapledon Society	BeefQ Project	Pip Nicholas-Davies
06-Mar-20	Aberystwyth University	Masters Seminar	5 Masters students	Masters Students	BeefQ Project	Pip Nicholas-Davies
04-Feb-22	Virtual	Lecture to students at Llysfasi College	10	Agri students	BeefQ Project	Pip Nicholas-Davies
15-Feb-22	Aberystwyth University	2 hour lecture to Masters Students	12	Agri students	BeefQ Project	Pip Nicholas-Davies
22-23-Jun-22	Aberystwyth University	2 day CPD event for FE College Lecturers	14	Agri FE College Lecturers	BeefQ Project	Pip Nicholas-Davies