AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

Hot carcase grading:
driving quality assurance and processing efficiency

Contents

1.0 Executive Summary

The "Hot Carcass Grading: Driving Quality Assurance and Processing Efficiency" project, under Project Code 2020-1040, represents a transformative step in meat processing technology. This project's central innovation, the MEQ Probe, was designed to provide objective and efficient grading of beef and lamb carcasses directly on the slaughter floor. This technology aimed to tackle key industry challenges, such as the subjective nature of traditional meat grading and the absence of objective quality measures, particularly for lamb. The MEQ Probe's implementation aims to achieve:

- **Enhanced Product Consistency:** Providing greater product consistency through objective measurements.

- **Timely Decision-Making:** Enabling earlier decision-making by implementing grading on hot carcasses.

- **Efficient Adoption:** Ensuring fast and seamless technology adoption with a design optimized for easy implementation, requiring no infrastructure changes.

Throughout the project's phases, including discovery, build-test-iterate-validate, and demonstration, the MEQ team collaborated with leading meat processors in Australia to develop and validate this novel technology. The MEQ Probe demonstrated its ability to measure intramuscular fat (IMF) in lamb and marbling scores in beef.

The MEQ Probe has demonstrated exceptional accuracy in lamb IMF measurements, beef ultimate pH, and beef marbling,, surpassing industry standards set by MSA guidelines. The MEQ Probe has shown its potential to revolutionise carcass grading, offering real-time, reliable data that can significantly enhance quality assurance, processor profitability, and transparency in the supply chain.

2.0 Introduction

The AMPC-funded project, embarked on an ambitious journey to transform meat grading processes. Initiated in response to the industry's need for more objective and reliable meat quality assessments, the project's primary goal was to develop a technology capable of real-time, accurate, objective grading tool for beef and lamb carcasses. The MEQ Probe, the centrepiece of this project, was developed through collaborative efforts involving industry experts, machine learning engineers, and meat processing professionals.

Purpose of the Research Project:

At its core, this research project seeks to transform the meat processing industry by introducing the MEQ Probe, a technology designed to grade beef and lamb carcasses on the slaughter floor objectively. The primary purpose is to alleviate the industry-wide demand for objective grading, driven by the subjective nature of traditional grading methods. MEQ aims to enhance product consistency, facilitate earlier decision-making, and provide valuable data feedback to producers, ultimately contributing to improved transparency and trust along the supply chain.

Background Information:

The motivation for this project emerged from three years of extensive collaboration with meat processors, wherein the feedback underscored the industry's need for a more objective grading system. The subjective nature of current grading practices has faced scrutiny from producers, industry bodies, and regulatory entities, prompting the need for innovation. The project builds upon MEQ's prior efforts, leveraging insights gained through partnerships with industry leaders, including Teys Australia and Gundagai Meat Processors.

Scope of the Research:

The scope of this research is multifaceted, encompassing the development and commercialisation of the MEQ Probe, with a specific focus on objective grading of beef and lamb carcasses. The technology aims to measure key attributes such as Marble Score (MSA), Intramuscular Fat (IMF), and pH on hot carcasses, thereby addressing existing limitations in grading accuracy and consistency.

Relevance of Previous Research:

Building on previous research initiatives, MEQ has strategically collaborated with the Australian Institute for Machine Learning, drawing on expertise in deep neural networks and signal processing. The decision to collect 12,000 samples is informed by insights from machine learning experts and aligns with the industry's need for advanced modelling techniques to ensure the technology's adoption. The project also incorporates lessons learned from past trials, including those with ACC and Oakey Beef Exports, reinforcing the robustness of the MEQ Probe.

3.0 Project Objectives

The intent of this project is to commercialise and easily adoptable technology enabling meat processors to efficiently and objectively grade their beef and lamb carcases on the slaughter floor. The objectives set for the project:

1. **Quality Assurance:** Ensure product quality through reliable objective grading data.

2. **Consumer Trust:** Build consumer trust and loyalty by delivering consistent product quality.

3. **Timely Grading:** Provide timely grading data early in the production process through a hot grading system.

4. **Data Feedback:** Offer accurate, repeatable data feedback to producers for informed decision-making.

These project objectives aim to be achieved with the following milestones

Phase 1: Discovery

- Trial design in consultation with Independent Scientific Advisors for collecting 10,000 intramuscular fat samples for both beef and lamb.

- Installation of probes at one beef and one lamb plant.

Phase 2: Build-Test-Iterate-Validate

- Collection of 10,000 lamb IMF samples and 10,000 beef IMF samples.

- Collection of 50,000 beef MSA marbling and ultimate pH samples.

- Ongoing validation and testing of models for robustness.

- Machine Learning development based on an increased sample size to 12,000.

Phase 3: Demonstration

- Validation of outcomes achieved in Phase 2.

- Repeatability demonstrated across four validation trials.

- Validation into the MSA system.

- Blind predictions using the probe, retrospectively comparing ground-truthed data from lab or grading sheets.

4.0 Methodology

In this study, we systematically collected 12,000 lamb IMF samples and 50,000 beef samples encompassing MSA marbling and ultimate pH measurements. Additionally, we developed Machine Learning models, reinforcing the robustness and predictive capabilities of our technology.

4.1 Lamb IMF Sampling

Lamb trial protocols were developed from the Sheep Cooperative Research Centre guidelines.

Process Overview

1. Measurement of IMF on the kill Floor by the MEQ Probe

2. Collection of samples for laboratory analysis

3. Measurement of laboratory IMF

4. Preparation of statistical report

Measurement of IMF on the kill Floor by the MEQ Probe:

The MEQ Probe is a hot measure of IMF% for lamb, located on the kill floor, just prior to the carcass weigh station.

The probe is integrated within the chain allowing for measurements of IMF on all carcasses processed at chain speed. An RFID system is utilised to identify and track carcasses throughout the plant. To ensure data integrity throughout the accreditation trial process, MEQ will use an RFID sensor to link MEQ data to carcass data. This will enable carcass tracking throughout the plant.

Lamb Carcass Selection Process:

1. Approximately 12000 lamb carcasses will be collected over the trial

    a. The final sample number will ensure that a wide range of the population is covered, delivering greater value to the industry.

2. Immediately after probing, carcasses are weighed and a unique carcass ticket is generated and attached.

    a. The carcass ticket is a unique identification that matches and stores the RFID and other carcass details

3. Selected carcasses are then sorted onto MEQ-specific chiller rails

    a. Once a carcass is probed and selected by MEQ, a selection request is sent to the sorting system

    b. The selected carcasses are then automatically sorted onto the MEQ chiller rails

4. The following day, the lambs on the MEQ chiller rails are stamped with food-safe ink for identification.

    a. The numbers are stamped sequentially from 1 to the number of lambs selected on the day.

    b. Each barcode, which is attached to the hook, has the corresponding stamped number written on it.

Collection of Samples for Laboratory Analysis:

Loin Sample Collection:

A 50-70g loin sample will be collected by MEQ from each cold carcass and will be tested for IMF %. The carcase will be sampled as follows:

1. All sampling was conducted at Gundagai Meat Processors.

2. On the following day of slaughter, the selected carcasses will be removed from the chiller as a group.

3. Lambs are processed through the standard boning process until the point where the barrel is split into the loin and rack portions.

    a. The loin portion is then taken from the conveyor belt where it is matched with the corresponding barcode ticket. The ticket is rematched with the barrel by linking the stamped number to the barcode ticket number.

4. The short loin (same side as what was measured by the MEQ Probe) is removed from the saddle from the 12th/13th rib to the 5/6th lumbar vertebrae.

5. The short loin is completely denuded, with all subcutaneous fat and silverskin removed.

6. The sample is diced and placed into a pre-weighed and labelled jar.

    a. The jars will be labelled with the carcass barcodes and directly recorded into the system.

    b. This method removes the need for a table to match the carcass barcode to a jar label.

7. The sample is frozen and then shipped to a commercial freeze dryer (Bio-Tech Freeze Drying, Knoxfield, VIC) where it is freeze-dried.

8. The samples will be returned by courier directly to MEQ Probe, where the samples will be re-weighed, ground, and then analysed using a Soxhlet calibrated lab-based NIR method to determine freeze-dried fat% content.

Statistical Analysis

MEQ have and use proprietary deep learning architecture that is designed for spectral processing to develop models to convert the spectral data into IMF% outputs.

4.3 Beef Marbling and pH Sampling

MEQ Probe is a solution for measuring the Marbling in beef on the hot side of processing plants. The MEQ Probe was installed in the Teys Wagga Wagga plant in November 2020. With the continued concerns of COVID during this time, it was decided to deploy a second beef unit into Australian Country Choice (ACC) Brisbane in May 2021. MEQ relocated staff members to Brisbane which allowed the continuous use of the MEQ Probe during a time when travel and access to food processing plants was particularly difficult. Through the use of these probes MEQ has undertaken an extensive research and development program, which has resulted in the development of a commercial product for the benefit of the red meat industry.

Measurement of Marble Score on the kill floor by the MEQ Probe:

The MEQ Probe is a hot measure of marbling for beef, located on the Slaughter floor. The location of the MEQ Probe at Teys Wagga and ACC Brisbane is just after the chine bone saw on the hot chain.

At both Teys and ACC, a site employee uses a chine bone saw to first cut the chine bone. The MEQ Probe is then inserted into the ribeye muscle at the 12th/13th rib where the measurement is made. The probe will be inserted and removed two (2) times to capture spectra and make marble scores for each carcass.

Probing Methodology

To perform a scan using the MEQ Probe the following actions are taken:

1. The carcass about to be scanned is identified using the abattoir's identification method of choice.

2. The operator identifies the 12/13th rib, and stabilises the carcass.
    The operator presses the button and inserts the MEQ Probe into the carcass at the 12/13th rib.

3. Keeping the button pressed the operator slowly draws the MEQ Probe out of the carcass at an approximately constant speed. This action is performed twice. The MEQ Probe provides feedback to the operator confirming the speed is correct.

4. Once the MEQ Probe has been fully extracted from the carcass, the operator releases the button, which completes the scan.

5. On the following day, the carcass was graded by the abattoir.

6. The kill data, MSA marbling score and pH value for each carcass were provided to MEQ for data processing.

Statistical Analysis

MEQ have used proprietary deep learning architecture that is designed for spectral processing to develop models to convert the spectral data into marbling outputs.

5.0 Project Outcomes

The key outcomes of this project are as follows

Lamb Summary:

- MEQ Probe was successful in identifying 'premium' lamb category (IMF > 4.7%).

- MEQ Probe was successful in drafting lambs into low, medium, and high categories.

- Maintained continuous IMF output from 2% to 10% with high accuracy and precision.

- MEQ Probe surpassed MSA guidelines and requirements for making IMF measurements in Lamb

Beef Summary:

- Ensured continuous MSA marble score output within AUSMEAT standards.

- MEQ Probe was successful in determining high ultimate pH carcasses (pH 5.71 and above).

- MEQ Probe surpassed accreditation standards as a marbling measure in beef

- IMF as a measure was not completed by MEQ through mutual decision of AMPC and MEQ. There has not been a consensus on how to best utilise the trait for commercial benefit, and as such no trials were conducted by MEQ.

The specific outcomes of the project are discussed below:

5.1 Lamb IMF

The project outcomes that related to lamb were initially outlined as:

1. Be 90% accurate in identifying a 'premium' lamb category, with premium being defined as an IMF percentage greater than 4.7%

2. Be 85% accurate in drafting lambs into three categories - low, medium and high - to allow for greater consistency in the consumer experience

3. Continuous output of IMF measure from 2% to 10%

A MEQ probe was ready for use at GMP as of 4th January 2021, which is within the allocated time. It has remained continuously operational since this time.

Figure 1: Callan Daley (MEQ Field Team Member) probing carcasses with the MEQ Probe

Figure 2: Photo of MEQ unit that powers the probe and the probe in its holster.

5.1.1 Statistical Results of Validation

Over the course of the project, MEQ was able to successfully build a tool that is able to determine the IMF% of lamb. MEQ undertook a blind validation to assess the performance of the tool.The MSA guidelines require technologies to be accurate to +/- 1% IMF on at least 68% of samples collected, and at least 95% accurate for +/-2 % IMF. The IMF range for the lambs captured in the population from this experiment covered the range from 2.06% IMF to 9.46% IMF. The distribution of the population's IMF is shown in Figure 3.
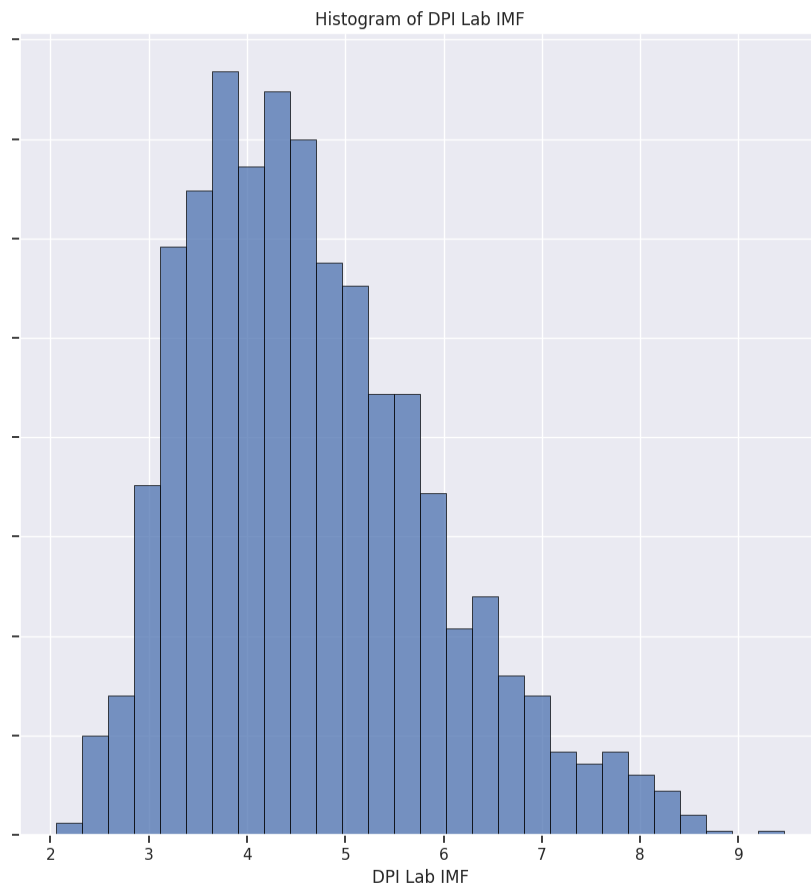
Figure 3: Distribution of DPI Lab IMF in the sample population ranging from 2.06% IMF to 9.46% IMF.

The results from the validation have demonstrated that the MEQ probe meets and surpassed the industry standards and requirements for use as a tool to determine IMF in lamb. The MEQ probe has subsequently completed MSA accreditation trials and is a fully accredited tool for determining IMF in sheep meet.

5.2 Beef

The project outcomes that related to beef are:

1. Continuous output of a MSA marble score within the AUSMEAT national accreditation standards

2. Be 90% accurate with high ultimate pH identification predictions of pH 5.71 and above

3. Continuous output of IMF measure from 2% to 15% for input into the MSA model

The probe was installed at Teys Wagga Wagga in 2020. However, given the COVID environment, it wasn't possible to gain continued access to the TEYS plant and as such MEQ Probe invested in deploying another unit at Australian Country Choice (ACC) in Brisbane.

Statistical Results of MSA Marbling

MEQ probe over the duration of the project collected spectral data from 20000 carcasses. The range of MSA marbling scores was 190-730. From this data collection, MEQ have used machine learning and deep learning to build predictive modules to deliver MSA marble scores. The distribution of the captured training dataset can be seen in Figure 4.
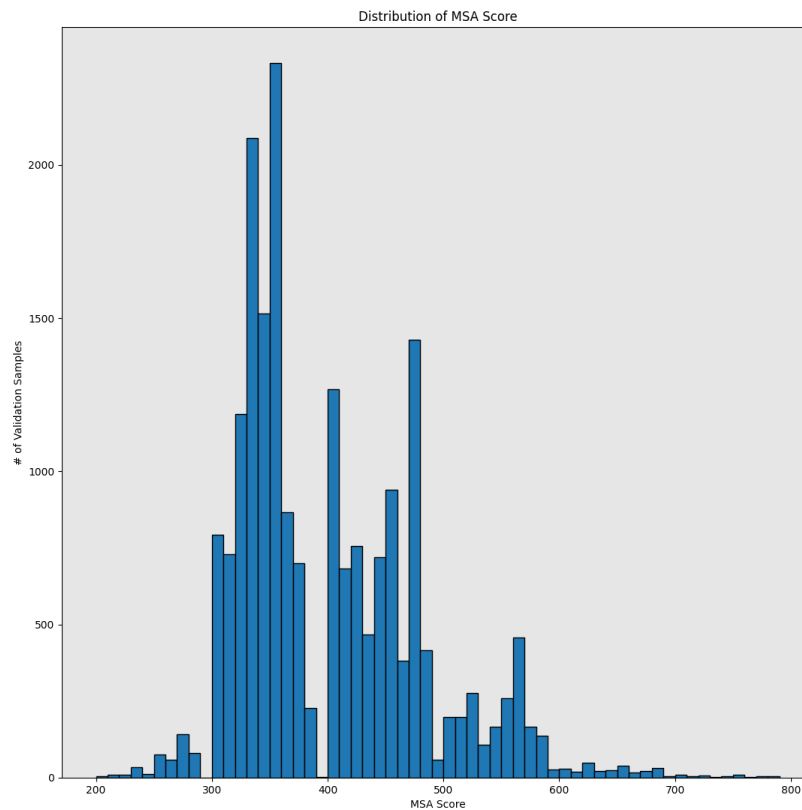

Figure 4: Distribution of the MSA marbling grading data from the validation sample data.

The MEQ probe underwent an internal validation process to demonstrate that the performance is within the Meat Standards Australia (MSA) accreditation guidelines. Carcasses were probed by the MEQ Probe at Australian Country Choice (ACC) recording the measured MSA Marble Scores. The carcasses were then graded by 2 MSA expert graders and a plant grader. The population of MSA marble scores ranged from 150 to 1140. A total population of 528 carcasses were included in the hold-out testing dataset. The MSA marbling range captured in this population of beef covered a range from 150 to 1140. The distribution of the population's marbling is shown in Figure 5.

The MSA proposed guidelines require technologies to be accurate to +/- 50 on at least 49% of carcasses, +/- 100 on at least 79% of carcasses and at least +/- 200 on at least 97% of carcasses. The results of this validation demonstrate that the MEQ Probe meets and surpasses these metrics as a marbling measure in beef.
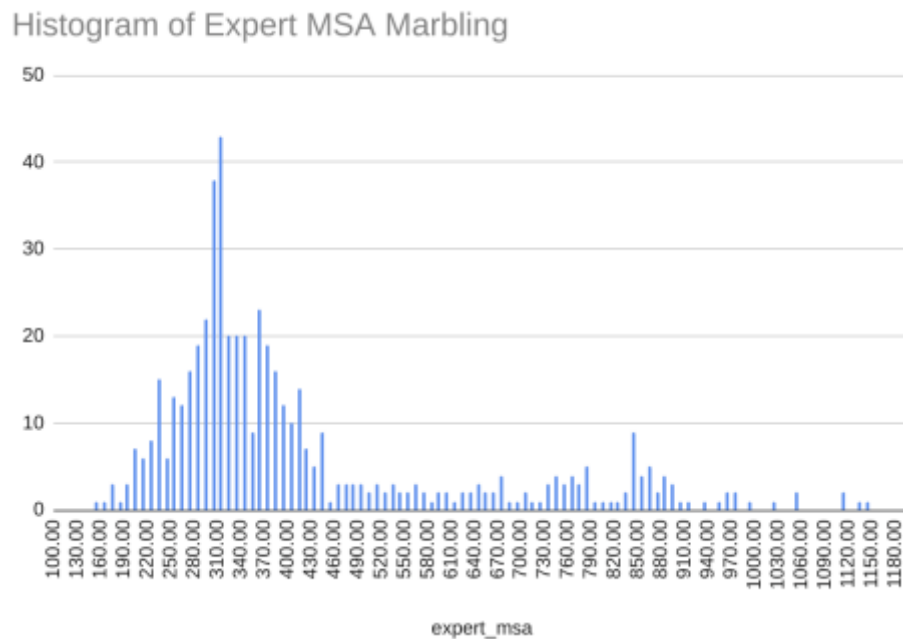
Histogram of Expert MSA Marbling

Figure 5: Distribution of MSA marble scores in the validation sample population ranging from 150 to

1140.

Statistical Results of pH Data

A model has been built using spectra to predict final cold pH. The model has been built for the purpose of carcass sortation. The model architecture favours a design that enables a portion of the population to be sorted out that has a high concentration of high pH carcasses.

For the purpose of this report, high carcasses are regarded as carcasses in the top 30% of the distribution.

During the tool validation, a total of 1000+ carcasses were assessed where the MEQ probe was successful in identifying carcasses with what would be deemed a high pH. This resulted in a sorting accuracy of 91.7%

Beef IMF

The industry aimed to establish beef IMF as a recognised trait. MEQ had already made advancements in IMF detection for lamb. Following discussions with AMPC, MEQ opted to delay IMF trials until the industry could reach a consensus on how to utilise IMF for the benefit of the industry. As a result of this, there was a mutual agreement not to undertake this part of the project and to potentially reassess during a future project. Unfortunately, MEQ was unable to complete this objective as part of the project.

6.0 Discussion

The project exceeded the initial target of 10,000 lamb IMF samples, accumulating a total of 22,000 samples across various MEQ trials. Similarly, over 100,000 beef carcasses underwent probing and analysis for MSA marbling, with 20,000 further analysed for ultimate pH. A strategic decision was made in collaboration with the Australian Meat Processor Corporation (AMPC) to forego beef IMF collection, recognizing the lack of clarity in current industry needs.

Following discussions with AMPC, adjustments were made to the lamb and beef outcomes. For beef, the initial target of continuous IMF output with R2 0.75 and RSME <1% was discarded due to the absence of IMF trials. Both lamb and beef outcomes were realigned with industry parameters, with a mutual decision to adopt industry-accepted guidelines instead of arbitrary classifications like 'low, medium, and high' for lamb.

Validation trials demonstrated that the MEQ Probe outperformed industry standards outlined by the MSA guidelines.

Despite challenges posed by the COVID-19 pandemic, the partnership with Teys Wagga Wagga was supplemented by additional data collection at Australian Country Choice (ACC) in Cannon Hill, Brisbane, QLD. This strategic move not only addressed limitations on processors during the pandemic but also provided a more diverse dataset, particularly with high-value, high-marbling Angus and Wagyu cattle. Additionally, repeat participation in expert grader accreditation trials at ACC enhanced insights into probe data and further enriched the study's outcomes.

7.0 Conclusions / Recommendations

The AMPC-funded meat grading project, culminating in the development and validation of the MEQ Probe, marks a transformative milestone in the meat processing industry. The project's overarching objective to introduce a technology capable of real-time, accurate, and objective grading for pre-chiller beef and lamb carcasses has not only been achieved but exceeded expectations.

The MEQ Probe has demonstrated accuracy and reliability in grading key attributes, such as Intramuscular Fat (IMF), Marble Score (MSA), and ultimate pH, surpassing industry standards and accreditation requirements.

The project's adaptive approach, informed by insights from previous trials and collaborations, facilitated successful navigation through challenges, including the impact of the COVID-19 pandemic. The strategic decision to collaborate with Gundagai Meat Processors, Teys Wagga Wagga and Australian Country Choice diversified datasets, providing a comprehensive understanding of the probe's performance across different settings.

The MEQ Probe's ability to meet and exceed industry guidelines and standards, as demonstrated in lamb and beef trials, positions it as a game-changer in the meat processing landscape. This technology not only addresses the longstanding demand for objective grading but also contributes to enhanced transparency, consistency, and trust along the entire meat supply chain.

Looking ahead, the successful commercialisation and adoption of the MEQ Probe have the potential to transform meat grading processes globally. This innovative tool not only provides meat processors with a reliable, efficient, and objective means of ensuring product quality but also opens avenues for many other benefits:

Beef:

- **Early cut planning:** A strategic approach to match supply with demand at the earliest point, enhancing overall operational efficiency.

- **Optimising chillers:** This facilitates energy savings and boosts throughput, aligning with sustainability goals.

- **Consistent product delivery:** The MEQ Probe ensures a uniform product with inherent efficiency, meeting consumer expectations consistently.

- **Efficiency optimisation:** Reducing carcass handling and expediting bonding runs, contributing to streamlined processing.

- **Chiller-grade efficiency:** Real-time grading before entering the chiller not only ensures accuracy but also maximises marshalling room efficiency, minimising space requirements.

- **Dynamic slaughter floor adjustments:** The ability to modify cut specifications on the go, in real-time and according to brand requirements, enhances yield and labour efficiency.

- **Consistent consumer experience:** Every plant, every day, promises a uniform product, ensuring reliability and trust in the consumer experience.

- **Quality feedback loop:** Providing valuable insights to farmers fosters continuous improvement in practices, contributing to enhanced overall product quality and consistency.

Lamb:

- **Objective Grading:** First hot carcase tool to allow carcass by carcass grading on eating quality

- **Improved Meat Quality:** Higher IMF content is often associated with better meat quality, including tenderness, juiciness, and flavor. This leads to a more desirable product for consumers.

- **Standardisation and Grading:** IMF measurements can be used in meat grading systems to standardise quality, helping consumers make informed choices and supporting fair pricing in the market.

- **Chiller-grade efficiency:** Real-time grading on hot carcasses allows for efficient chiller sortation and unlocks product differentiation

- **Product Differentiation:** By offering lamb with specific IMF levels, producers can differentiate their products into competitive markets, appealing to niche markets or premium segments.

- **Market Pricing:** Sheep with higher IMF levels can command higher prices in the market, providing an economic incentive for producers to breed and raise sheep with higher IMF levels.

- **Breeding Programs:** Knowing the IMF content helps in selective breeding programs aimed at improving meat quality. Producers can select breeding stock based on their IMF levels, leading to a genetic improvement in the flock.

- **Consumer Satisfaction:** As consumers become more discerning, offering meat with higher IMF can meet consumer demand for premium quality products, enhancing customer satisfaction and loyalty.

The MEQ Probe augments traditional grading, providing a solution that optimises various aspects of the meat processing industry when used in conjunction with existing practices. This promises a future of increased efficiency, sustainability, and quality throughout the industry.

The project outcomes underscore the importance of collaborative efforts between industry experts, machine learning engineers, and meat processing professionals in driving innovation that aligns with industry needs.