



Final report

Ovine IMF – MARBL™ Twin Sensor Production System Development & Installation

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Abstract

The objective of this project was to complete the 1st commercial installation of a fully automated system for measuring percentage of intramuscular fat in lamb. The completed system was to be installed in-line and operated at processing line speeds of between 8-12 carcasses/minute.

The technology that underpins this project is the Marbl™ sensor, a sensor that uses magnetic resonance to non-invasively and directly measure a volume of meat within the backstrap.

At the time of writing a system has been designed, built, installed and partly commissioned. To achieve the required line speed, the system has two adjacent Marbl™ sensors and carcasses are shuttled in in pairs. This design extended prior proof work using a single sensor design i.e. a Production Prototype that was temporarily installed, and a system installed in-line and operated at processing speeds of 4-5 carcasses/minute for 12 months.

We showed we could complete the full cycle in around 10 seconds, that is, carcasses identified, shuttled in, pushed against the pivoted Marbl™ sensors, measured for %IMF (in around 5 seconds), data recorded, and shuttled out. This is equivalent to 12 carcasses/minute. At the time of writing, the system has been operated for short periods. %IMF measurements were in the range we might expect based on prior work i.e. 2- 9%. Further work is required to tune and optimise the system, validate the IMF measurements then seek AUSMEAT accreditation.

This project supports the Australian red meat industry strategy of objective trait measurements that support the sheepmeat MSA cut-by-cook models, where intramuscular fat is a key trait.

This project was kindly supported by MLA, AMPC and JBS. The equipment has been installed in JBS Bordertown.

Executive summary

Background

Red meat traits are graded using manual and primarily visual subjective methods. Not only are these manual grading methods tedious they are also open to inaccuracies. Developing objective measurement methods to capture more accurate data to support alternative pricing methods for producers is an industry strategic 2025-230 imperative.

There are several objective measurement technologies at various stages of validation and accreditation for grading red meat traits. This project was submitted in response to MLA open call for co-investment proposals from businesses seeking to trial and adopt emerging objective carcass and/or live animal assessment technologies. The opportunity was open to all technologies for businesses to test and trial integration of developing equipment, and, where applicable, software to enable MSA grading outputs from these technologies to plant systems.

Marble score is a key carcass grading characteristic for both MSA and AUS-MEAT grading, and domestic and international market requirements. Recently, the Australian Meat Industry Language & Standards Committee [AMILSC] has approved intramuscular fat percentage (IMF%) as a trait in the AUS-MEAT language. This opens the opportunity for objective measurement devices to be trained to measure both IMF% and marble score.

Intramuscular fat (IMF) is key trait influencing the eating quality of lamb and sheepmeat. MLA has made significant investment to develop a new sheepmeat MSA model to evolve from a mob-based pathway to a cut-by-cook model, as is well established for the beef industry. A key trait required for the MSA MKII model is IMF%. Subsequently, development of technologies to measure IMF in hot carcasses at chain-speed is a high industry priority and a core focus of MLA's objective measurement program.

Importantly, the Australian Meat Industry Language & Standards Committee has recently approved intramuscular fat percentage (IMF%) as a trait in the AUS-MEAT language. This opens the opportunity for objective measurement devices trained to measure IMF% to be used in commercial trading thereby enabling industry to adopt the new MSA cut-by-cook model and introduce new value-based trading options.

Following proof-of concept studies of the potential of NMR in 2021, in 2022/23 inMR Measure Ltd (inMR) developed a prototype, automated nuclear magnetic resonance (NMR) system to measure IMF% in hot lamb carcasses and demonstrated utility under abattoir conditions [1-3]. The prototype was installed temporarily off-line. Over 1000 carcasses were measured and a set (N=137) were referenced against the gold standard IR method. The results showed the reference data set passed the MSA accreditation between 2 – 6% IMF when tested on the Murdoch University web app. Due to a lack of samples outside this range it was not possible to test below 2% or above 6% IMF. Further, accuracy estimates of 1% variation were in line with the AUS-MEAT accreditation limit.

Additionally, inMR have developed a proof-of concept system to measure IMF% of sub-primals in a beef boning room. This unit delivered a prediction accuracy of R^2 of 0.97 and RMSEP of 1.3 IMF% providing confidence to further develop a beef system that delivers non-invasive measurement in an automated inline configuration [4].

The magnetic resonance method measures a volume (3-5cm³ for lamb) of meat beneath the surface and is non-invasive.

This project seeks to progress from the production prototype to a 1st commercial installation. A successful project will show the technology fully operational, in-line, at Australian chain speeds.

Objectives

The overall objective of the project is to build on the learnings from prior work and to design, build and calibrate an automated in-line inMR, Marbl™ system to measure IMF% in hot lamb carcasses.

The specific objectives of the project include:

- Develop, design and build a twin sensor system
- Prove the design can operate at chain speeds of 8-12 carcasses/minute. First in the workshop and then in a processing facility
- Install the Marbl™ system at an Australian lamb processor
- Initiate AUSMEAT accreditation of the equipment in the installation
- Feasibility and business case to validate the return on investment

Methodology

The project was conducted in the following two stages:

Stage 1 was the design, build and testing of the system. This work will be conducted in an initial startup project planning workshop with the MARBL™ twin sensor production system development & installation Project Steering Committee. An Expression of Interest was written to identify interested in-kind processor partners. The final testing milestone sought to confirm that the outcomes are achievable, most importantly operating at chain speeds using an equipment layout that would be fit for purpose.

Stage 2 was the site specification, preparation & freighting, installation & commissioning (Milestone 5), operation, accreditation and final reporting. This work would all be conducted at a processor site.

Between Stages 1 and 2 a Go/No Go stage gate and budget review were included. Progressing with Stage 2 would require commitment from a processor with respect to facility preparation to accommodate the equipment; this was beyond the scope of this project and was managed separately by AMPC/MLA.

Results/key findings

Processing Partner – JBS Bordertown partnered with inMR, AMPC and MLA on this project. JBS Bordertown also partnered with inMR on the earlier Production Prototype project following which options for locating an in-line system were discussed. This continuity of development projects has proven invaluable with respect to understanding the site, staff and product. Further, JBS has committed to individual carcass identification and data integration towards leveraging the benefits of objective measurements to leverage the MSA sheep meat pathways.

JBS settled on locating the inMR equipment at the end of the harvestfloor, opening additional adjacent space in an existing underutilised room. This location had pretty good access for installation of the equipment.

Design – the initial concept was modelled on designs from two prior pieces of work, that is, the Production Prototype and a single sensor system that was installed and operated for a year in a processing facility that was operating at chain speeds between 4 – 5 carcasses/minute. From the outset we were aware two Marbl™ sensors would be required to operate in-line at processing speeds of 8 – 12 carcasses/minute.

Other key design considerations for the system included:

- Cycle time of around 10 second for the measurement of two carcasses
- Marbl™ sensor measurement times of around 5 seconds, with the rest of the cycle time being used for carcass in-feed, carcass positioning and carcass out-feed.
- Managing carcass movement: in-feed, swing, orientation, spacing
- Operating modes: Fully automatic for routine measurements and Bypass to manage surges in carcass flow
- System Footprint: the main frame dimensions are 2500x1600x2000 mm (LxDxH)

Marbl™ Sensors – The unilateral magnetic Marbl™ sensors are designed for the application and the design was informed by projects, i.e: the alpha prototype [1], the beta used in the Production Prototype [2] and a full wash-down ready version used in a NZ-installation. The magnetic field strength of each sensor was around 0.17T (Frequency of operation around 7.2MHz) and the volume of interest, that is the volume of meat being measured in the backstrap, was 5cm³ and was tailored for Australian lamb. The sensors are typically operated at 28 +/- 0.1°C and are tuned using bespoke automated electronics and controlled using off the shelf spectrometers. The sensors were all shown to be built to the required design specification.

The stainless steel housing of the Marbl™ sensors is shaped to assist with positioning of the carcasses.

Development was required to:

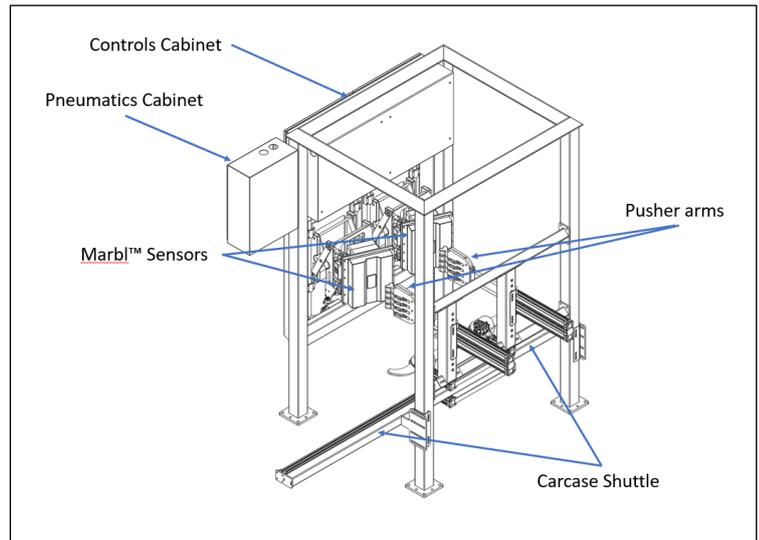
- reduce the %IMF measurement time from the 30 seconds used in the Production Prototype work [2], and the 8.2 seconds used in in-line single sensor system installed in NZ or a year. The measurement time at acceptance testing was under 5 seconds.
- avoid radio frequency interference, this was achieved by interleaving the multiple scans made on each sensor.
- manage safe installation of the sensors. With the sensors being strong magnets, an installation jig had to be designed to ensure they could be positioned at 600mm centres.

In line with AUS-MEAT accreditation requirements a check method has been developed. A known solution is measured on the tuned sensors.

Balance of Equipment – Mechanical, Controls & Carcase Handling

In the main, the design of the balance of equipment replicated the single sensor system that had been used in plant for a year, i.e.: two single sensor systems sitting adjacent to each other with the addition of two new sub-systems: a carcase shuttle and pivoting Marbl™ sensors.

The equipment is installed with a stacker chain running through the measurement equipment. The system is fully automated with carcasses being shuttled in and out in pairs. Carcasses are pushed onto the sensors using pusher arms



The shuttle includes grabbers that crowd each carcase and prevent carcase swing when being moved. This assists with locating the carcasses in front of the Marbl™ sensors.

The Marbl™ sensors pivot to allow the pairs of carcasses clear entry to their measurement locations and clear exit.

Along with various automation equipment (e.g. PLC, control sensors, pneumatic valves and rams), the system is fitted with two remotely accessible surveillance cameras and a mount for a QR-reader. %IMF measurements are stored on the spectrometers along with timestamps and key equipment operating parameters.

Finally, being the 1st-of system, as much flexibility as possible has been designed in.

Workshop Development & Testing

Stage 1 of this project concluded with a Go/No Go stage gate. Critical to progressing to stage 2 was proof that the system could operate at chain speeds of up to 12 carcasses/minute.

On the back of development work, limited testing with carcasses in the workshop showed we could complete the full cycle, that is, carcasses identified, shuttled in, pushed against the pivoted sensors, measured for %IMF, data recorded, and carcasses shuttled out, in around 10 seconds. This is equivalent to 12 carcasses/minute.

On this finding we progressed to Stage 2.

Installation, commissioning and early preliminary data

The equipment was installed at JBS Bordertown in early June 2025, see photos.



At the time of writing, the system has been operated for short periods over several days. The extent of use was limited by commissioning delays with the stacker chain and some necessary improvements; the main one being at the carcass in-feed. That is, the carcasses waiting are being stacked too close to the pair to be shuttled in, obstructing the grabbers. Irrespective, through manual management of a 'gap' we showed that the equipment operating and obtained preliminary %IMF results.

%IMF measurements were in the range we might expect from prior work i.e. 2- 9%.

From here further work is required to tune and optimise the system. In addition, work is planned to validate the measurements as preparation towards AUSMEAT accreditation. This work will be progressed over the next 4 – 6 months.

Benefits to industry

Intramuscular fat % is a measurement trait in the MSA eating quality framework for lamb. The outcomes of this project will deliver an automated objective measurement method for measuring IMF, supporting the potential value offered by the MSA system. We note that the beef grading system which is now commercial is delivering >\$200M to farm gate returns per annum so once the lamb MSA system is fully commercialized and in use – farm gate returns for lamb producers can also be significant. There is still work to do on the return on investment but if differentiated product can attract say a 10% additional return, payback could be significant.

Future research and recommendations

From here, future research needs to focus on validation and AUS-MEAT accreditation of the Marbl™ system, whilst in parallel, infrastructural systems (carcass ID and data) are developed and built and market opportunities quantified for differentiated lamb products. Following this, the door is open for facilitated adoption of the system within Australian processing plants.

In addition, being a robust, non-invasive technology, the Marbl™ sensor can be used further back in the valve chain, permitting %IMF measurement on farm. Research towards developing this application is underway.

MLA and AMPC welcome any further enquiries from interested industry and research partners.

References

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