Final report

Application of Marbl™ to Live Cattle IMF Measurement - Proof of Concept

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Abstract

Intramuscular fat (IMF) and marble scores are key value drivers in the beef industry; however, these are unknown until post-slaughter leaving much uncertainty for producers and processors. Nuclear magnetic resonance (NMR) technology was recently proven capable of measuring IMF content in hot lamb carcasses at the end of the slaughter floor. NMR is a non-invasive method related to medical MRI making it a good prospect for live animal IMF measurements.

This project tests whether NMR technology and an animal handling unit can be developed for measuring IMF of live cattle. A prototype NMR system was designed, built, and installed at an Australian research feedlot. Hundreds of cattle were scanned, and then reference samples were collected post slaughter. Data from this project show the system has excellent potential to measure IMF in live cattle.

Key benefits to industry include: understanding production over time (marbling, yield, weight gain, etc.); optimising production operations based on IMF data; better product allocation through more accurate sales forecasting; performance prediction early in production; sustainability impacts; and informed feeding regimes.

Executive summary

Background

There is significant value in the measurement of carcase traits. Intramuscular fat IMF) and the related marble scores are key value drivers in the beef industry, however, these are unknown until post-slaughter leaving much uncertainty for producers and processors alike.

Nuclear magnetic resonance (NMR) technology can measure fat content in food. This was recently proven by measuring IMF in hot lamb carcasses at the end of the slaughter floor. Magnetic resonance imaging (MRI) is a form of NMR that is a standard medical imaging technique making it an excellent choice for living animals. This project tests whether NMR technology and an animal handling unit can be developed for measuring IMF and marble score of live cattle. The results of this project will be used to inform the further development of NMR devices.

Objectives

The objectives of the project were:

- Design, build and test a proof-of-concept prototype Marbl™ sensor
- Evaluate a prototype sensor integrated into an animal handling crush for measurement of IMF% in live cattle
- Evaluate pre-commercial %IMF measurement protocols
- Preliminarily analyse and review correlations of NMR datasets with AUSMEAT marbling score and independent IMF% measurements
- Evaluate animal response and behavioural considerations for making such measurements

Methodology

- We designed, built, and tested a proof-of-concept prototype NMR sensor
- We integrated the sensor into a modified cattle crush for animal handling and positioning the sensor on the loin muscle.
- The NMR system was installed and commissioned a research feedlot in New South Wales.
- Hundreds of cattle were scanned
- The NMR data were processed to predict a live IMF for cattle
- Reference samples were collected post slaughter for chemical IMF determination
- The NMR data were compared to the reference data to evaluate the accuracy of the measurement

Results/key findings

We successfully installed an NMR device in a feedlot. Over the duration of the trials, iterative improvements contributed to successfully measuring IMF in live cattle. The NMR system was able to accommodate a large range of cattle breeds and sizes. Long delays between scanning and slaughter have hindered analyses of data and iterative development in IMF prediction. A small data subset shows the system has excellent potential to measure IMF in live cattle.

Benefits to industry

Key benefits to industry include:

- Understanding IMF production over time (marbling, yield, weight gain etc.) and optimising operations based on this data
- Better product allocation through more accurate sales forecasting
- Performance prediction early in production (induction and backgrounding included)
- Feedback to farmers directly from feedlot rather than tracking back from the processor
- Estimated breeding value IMF contribution measured directly rather than from sires
- Sustainability impacts by removing under performers resulting in:
    - Less methane production for same meat output
    - Fewer resources needed
    - Less waste
    - More efficient processing, where high fat cover requires more energy to chill

Future research and recommendations

- Establish methods for collecting consistent high-quality data
- More NMR measurements on a range of cattle to validate a robust IMF% prediction model
- Faster and iterative application development

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1. Background

There is significant value in measurement of carcase traits pre-processing. Each of these value propositions consists of different outcomes and processes required to be delivered. The main use cases that benefit producers include:

- Understanding production over time (marbling, yield, weight gain etc.) and optimising operations based on this data
- Better product allocation through more accurate sales forecasting
- Performance prediction early in production (induction and backgrounding included)
- Sustainability impacts

Successful application of Marbl™ to live cattle %IMF measurement would add value to producers by:

1. Providing IMF data, early, and generally allowing informed decision making.
2. Using the data to inform decision-making to turn feed on/off for optimal product outcomes
3. Allowing feedlots/producers to optimize branded product
4. Identifying higher-performing animal genetics

In addition, measurements at the feedlot would inform decision making for processing. Animals could be provided to processors in batches based on IMF as a key measure of eating quality. Further, sorting into chillers for subsequent manufacture could be more efficient as a result.

2. Objectives

The overall objective of the project is to design, build and test a pre-commercial proof of concept Marbl™ sensor system for the purpose of obtaining cattle intra-muscular fat (IMF) data.

The specific objectives of the project were:

- Design, build and test a proof-of-concept prototype Marbl™ sensor
- Evaluate a prototype sensor integrated into an animal handling crush for measurement of IMF% in live cattle
- Evaluate pre-commercial %IMF measurement protocols
- Preliminarily analyse and review correlations of NMR datasets with AUSMEAT marbling score and independent IMF% measurement
- Evaluate animal response and behavioural considerations for making such measurements

3. Methodology

3.1 NMR equipment

The sensor was designed from a specification based on the cattle expected to be measured. This included shape, size, range of skin thickness, and subcutaneous fat thickness. A safety margin was then added on top of this to make sure most animals could be accommodated. This resulted in designed sensitive volume of roughly 180 cm^3. This is comparable to the sample size for gold standard IMF% measurements of beef, which are nominally 200g (Stewart et al., 2020). The magnet was built as designed (Fig. 1). We also built a custom NMR spectrometer with Resonint Ltd. (Wellington, New Zealand) to handle the stronger radio frequency (RF) power required.

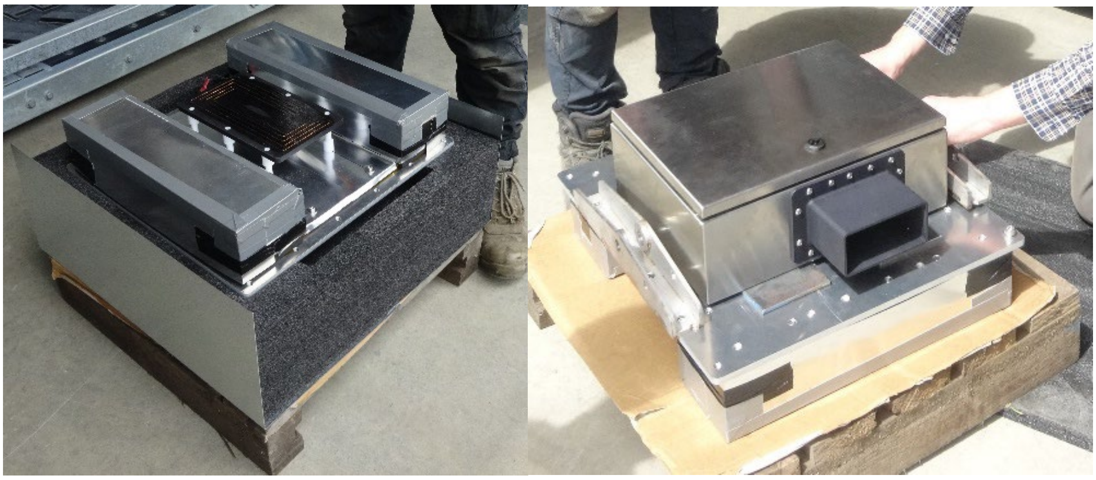

Figure 1 – Marbl™ sensor sitting on the packaging (Left). Magnet tower blocks and the RF pad (black) are visible. Electronics cabinet on the back of the sensor (right).

3.2 Animal handling unit design and build

We commissioned Advanced Engineering Solutions Ltd. (Feilding, New Zealand) to design and adapt a purchased cattle crush. The initial concept was a cantilever sensor mount on a cattle crush. In addition to accommodating the sensor mount, magnetic steel that might interfere with the measurements was removed. The crush comes with a squeeze mechanism to assist in pacifying the cattle. This was replaced with a pulley system to allow access of the sensor from above (Fig. 2).

Figure 2 – Initial build of the animal handling unit showing the cantilever assembly for positioning the sensor. Galvanised steel was replaced with stainless steel where necessary. A platform was constructed for the operator to stand on while making measurements.

3.3 Integration of sensor into animal handling unit

The sensor was integrated into the animal handling unit, which was then iteratively modified to fulfill the project needs (Fig. 3). These improvements included:

- Longitudinal (along length of animal) sensor position adjustment
- Lateral sensor adjustment
- Handles for manipulating the sensor height and tilt

Figure 3 – Marbl™ sensor, in position in the crush

3.4 Trial

The equipment installation included assembly, locating the crush along the race, fixing the crush in place, installing shelter from sun and rain, and startup and equilibration of the sensor to the environment.

The sensor's sensitivity to the environmental temperature was a known concern. The sensor performance is dependent on the magnet temperature and therefore, we want a stable magnet temperature. We addressed this sufficiently by adding insulation to the sensor to keep the temperature stable overnight.

Initial testing involved evaluating, the ability to control sensor location, the sensor fit on the loin muscle, animal response to the crush, animal response to the sensor, and time needed to collect NMR data.

Cameras were set up at the front and back of the crush at a low angle to observe how the sensor was sitting on the animal, its lateral location, and animal behaviour. We learnt:

- The sensor fit on the backs of the animals
- The sensor position adjustments were adequate to accommodate the huge range of cattle sizes (400 – 750 kg)
- Most animals were okay with being in the crush with different degrees of cooperation.
- Thinner animals require the squeeze to keep them straight in the crush.
- NMR data could be collected in about a minute

The remedial work was carried out during the initial testing and on the interim days between animal availabilities. We optimized the sensor handling to allow for better positioning of the sensor on the animal. Further work with animal handling experts is recommended.

3.4.1 Description of animals measured

A representative range of Australian beef cattle were measured over the course of the install and trial. The exact numbers of each breed and cross breed measured are shown in Table 1.

Table 1. Breeds measured.

Breed	Count
Angus	105
Charolais	20
Hereford	75
Shorthorn	48
Wagyu	21
Brahman	10
Angus Brahman	18
Hereford Brahman	19

Many of the animals were not killed before preparing this report. Further animals from the install and commissioning and development stage were also removed from the potential data pool. Some animals with anticipated behaviour problems were usually not measured to avoid damaging the NMR equipment. This left a small final subset of the steers and NMR measurements available for evaluation of the NMR prediction. The statistics for animal weights, behaviour, and chemical IMF % of this subset are shown in Table 2. The weights are from the morning of the scan, the crush score is a metric of animal behaviour during the NMR measurement (Section 3.4.2), and the chemical IMF is the percent intramuscular fat by weight as determined by calibrated NIR.

Table 2. Subset cattle statistics including weight at scan, crush score and chemical IMF %.

N=36	Mean	Median	Std. deviation	Range (min, max)
Weight at scan (kg)	591	584	48	478, 678
Crush score (1-5)	1.36	1	0.5	1, 5
Chemical IMF (%)	7.92	7.76	3.17	2.92, 15.57

3.4.2 Live animal NMR scanning protocols

The knowledge acquired during install and commission was used to create scanning procedures. The animal scanning process involved the following steps:

1. coax the animal into the crush
2. close the head bail and rear gate
3. insert the backing bar
4. allow the animal to settle
5. adjust the sensor position laterally and longitudinally
6. apply the sensor to the animal

7. start data collection
8. follow animal movement as needed
9. record matching NMR and ear tag IDs in the measurement log
10. record sensor position scores
11. record animal behaviour score
12. release the animal from the crush

The date, animal ID, NMR ID, sensor position, and animal behaviour were recorded in measurement log. Each animal was scored between 1 and 5 for sensor positioning and animal behaviour (crush score) with context of how this might influence the NMR data quality. Position scores of 3 were recorded when the sensor was positioned at the 13th rib and located laterally to be in the center of the loin muscle. Lower scores were recorded when the sensor was toward the spine or head and higher scores for the opposite. An animal behaviour score of 1 was recorded when the sensor sat in position for the duration of the data collection. A score of 5 was recorded if NMR data collection was not possible due to animal movement.

3.5 Gold standard reference measurements

Objective measurements of eating quality were made on them post slaughter. Gold standard IMF% measurements were performed at the accredited laboratory at the University of New England (UNE) using calibrated near infrared spectroscopy (Perry et al., 2001).

4. Results

A correlation coefficient of 0.35 and a root mean squared error of prediction (RMSEP) of 3.8% was calculated between the NMR predicted IMF and the NIR reference measurements. Partial least squares (PLS) was used to find a better correlation between the raw NMR data and reference IMF % for this new NMR sensor and application. Being careful to avoid false correlations when analysing limited data, such the filtered SMB32 dataset of only 36 samples, we used test train validation simulations to find the most likely correlation and RMSEP to be 0.38 and 2.87 % IMF, respectively. This IMF% error when related to AUS-MEAT marble scores is about one unit.

5. Conclusion

5.1 Key findings

- We measured a good range of cattle and find that their shape and size can be accommodated by our sensor design.
- The measurements can be made in under a minute if animal handling is streamlined.
- NMR measurements correlate with IMF showing that the application is possible.

5.2 Benefits to industry

Key benefits to industry include:

- Understanding intramuscular fat change over time (marbling, yield, weight gain etc.) and optimising operations based on this data
- Better product allocation through more accurate sales forecasting

- Performance prediction early in production (induction and backgrounding included)
- Feedback to farmers directly from feedlot rather than tracking back from the processor
- Estimated breeding value IMF contribution measured directly rather than from sires
- Sustainability impacts by removing under performers resulting in:
    - Less methane production for same meat output
    - Fewer resources needed
    - Less waste
    - More efficient processing, where high fat cover requires more energy to chill and process

6. Future research and recommendations

- Improve consistency of data quality
- Collect more NMR data on a range of cattle
- Fast and iterative application development
- Streamline animal handling

7. References

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