Final report

Translating intramuscular fat measurement technology to the beef industry

Project code:	V.TEC.1733
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Abstract

This project has assessed feasibility of a new device that allows beef processors to measure the percentage of intramuscular fat (IMF%) of a hot beef carcase immediately after slaughter. The device uses an optical imaging technology developed at The University of Adelaide, that has been successfully demonstrated with hot lamb carcases. It is being developed in collaboration with partner organisation, Miniprobes Pty Ltd. This device would allow beef processors to categorise meat quality early in processing, reducing costs in beef processing. It would also give Australian exporters a quantified measure of intramuscular fat, providing a differentiator against products from other countries.

In this project. we developed a prototype system and completed an initial feasibility study to estimate IMF% on 100 beef carcases from the Southern Multibreed herd. Our results showed a good correlation to gold-standard chemical estimates of IMF%, with an average absolute error of 1.4% and an r^2 correlation value of 0.56. A limitation of the prototype system was that it was primarily trained on lamb data. We identified there is scope to significantly improve these results in future projects by acquiring and training the analysis algorithm with additional beef data.

The project has established the feasibility of using this technology to estimate IMF% in hot beef carcases.

Executive summary

Background

Australia is a major exporter of beef. However, our average production costs are significantly higher than our competitors. An opportunity lies in supplying premium beef, which builds upon Australia's brand as a provider of high-quality agricultural products. There is a need to develop technologies to enable efficient quantification of meat quality early in processing, where potential cost savings in processing would be greatest.

Meat quality varies between individual cattle, so every carcase needs to be assessed to identify premium products. Previous MLA projects (V.TEC.1723, V.TEC. 1726) have supported the development of an optical scanner to measure intramuscular fat in lamb carcases. This project aimed to establish the feasibility of extending this technology to hot beef carcases.

Objectives

The objectives of this project were:

- Develop a prototype scanner for beef carcases by adapting a system previously developed for use in lamb.
- Establish feasibility of the scanner with an initial study of 100 beef carcases.

Both of these objectives were successfully completed.

Methodology

The key modification to the scanner hardware was to adapt it to scan deeper in the muscle, as beef carcases are much larger than lamb. This also required modification to the software to process the larger scan size in beef. This modified scanner was then validated in a trial with 100 carcases from the Southern Multibreed herd and validated against a chemical gold-standard estimate of intramuscular fat.

Results/key findings

We established feasibility of using this scanner in a commercial meat processing plant. We also obtained accurate estimates of the percentage of intramuscular fat. The average absolute error was 1.4%, and the RMSE was 1.8%. The r^2 correlation value was 0.56.

Benefits to industry

This technology has the potential to improve boning room efficiencies by allowing processors to sort beef carcases prior to chilling. We estimate a potential saving for the Australian beef industry of $21mil per year in improved efficiency.

Future research and recommendations

With support from MLA, we have secured funding for a follow-on project through the Commonwealth Department of Industry CRC-P grant program to complete translation of this technology for use in beef.

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1. Background

Australia is a major exporter of beef. However, our average production costs are significantly higher than our competitors: twice the cost of production in Brazil and 24% more expensive than the USA [1]. There is an urgent need to develop technology to provide our Industry with a competitive advantage to secure and grow our position as a global leader in the beef industry. Our most significant and profitable opportunity lies in supplying premium beef, which builds upon Australia's brand as a provider of high-quality agricultural products. Compared with Meat Standards Australia Grade 3 meat, studies show that consumers will pay an additional 50% and 100% for premium Grade 4 and 5 (highest quality) meat [2]. This is particularly important in markets such as Japan, which is one of our largest export markets, but where we are under competitive pressure from the USA.

Meat quality varies between individual cattle, so every carcase needs to be assessed to identify premium products. At present, this is done on the cold carcase after 1-2 days chilling.

This project assessed the feasibility of a new device that allows beef processors to measure meat-eating quality on the hot carcase immediately after slaughter. It does this by quantifying the percentage of intramuscular fat in the carcase. The fat consists of tiny deposits of oil (lipid) between the muscle fibres which increase the juiciness and flavour of the meat. A higher percentage indicates greater meat-eating quality [3].

The device uses an optical imaging technology developed at The University of Adelaide, and being commercialised by our partner organisation, Miniprobes Pty Ltd. The underlying imaging modality is optical coherence tomography, which is commonly used in human medical imaging [4]. Through parallel projects in the lamb industry (V.TEC.1723, V.TEC.1726), our team have developed a system to measure the percentage of intramuscular fat in hot lamb carcases. This device could allow beef processors to categorise quality early in processing, reducing logistics costs in meat production. It will also give Australian exporters a quantified measure of meat quality, providing a differentiator against products from other countries.

This project will adapt that system for use in beef carcases and complete a feasibility study. These results will be used to define future projects to develop the scanner for use in a beef processing plant.

MLA funding ($50k) for this project has been used to leverage $406k of additional funding from Australia's Economic Accelerator through the Commonwealth Department of Education.

2. Objectives

The 12-month project is separated into two phases with the following aims:

1. Develop a prototype scanner to Technology Readiness Level (TRL) 5, adapting the technology to measure beef carcases. This includes developing the hardware and software required for a beef hot carcase probe that can be deployed in a meat processing plant to measure IMF in commercial conditions.
2. Validate the system with a preliminary study of cattle (minimum 100 carcases) from multiple breeds and investigate securing additional funding. This includes undertaking trials to validate the accuracy of IMF measurement under commercial conditions, and in doing so compile a dataset to evaluate the device's ability to achieve AUS-MEAT approval for IMF measurement.

Both objectives were completed successfully within the scope of this project.

3. Methodology

3.1 Develop prototype scanner from TRL4 to TRL5

The first phase of this project was to develop a TRL5 prototype designed for use on cattle carcases. Our scanner comprises two parts: a control unit (which contains the computer, electronics, and optical scan engine); and a handpiece. The handpiece has 4 stainless steel needles, each containing two fibre-optic probes capable of imaging the tissue structure as it is inserted into muscle. Photos of the handpiece and control unit are shown in Figure 1.

Figure 1. (left) Handpiece, comprising 4 needles to perform multiple measurements simultaneously. (right) Control unit that is connected to the handpiece, mounted on a stainless-steel pole

Our earlier work had developed a handpiece for lamb carcases. However, this needed to be adapted for the larger carcases in a beef processing plant. This involved increasing the length of the needles for deeper penetration. Figure 2 shows the design of our original (lamb) hand piece, with 58mm long needles, and the revised (beef) handpiece with 98mm needles.
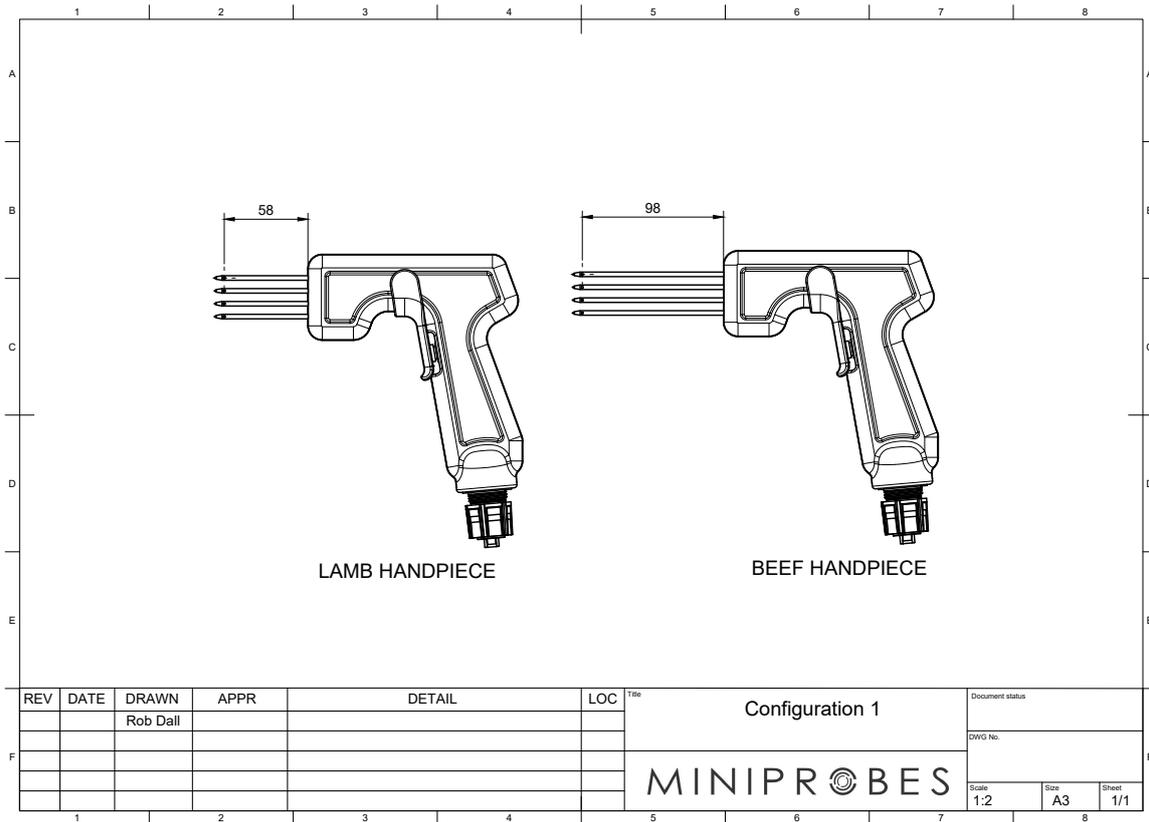
Figure 2. (left) lamb handpiece with 58mm long needles. (right) Beef handpiece with 98mm needles for imaging deeper into muscle.

An exploded engineering view of the TRL5 control unit is shown in Figure 3. This system has extended upon the engineering design previously developed in V.TEC.1723 and V.TEC.1726. In particular, we have improved the design of the connection between the electronics unit (containing computer, power, light source) and the handpiece. Earlier designs had separate optical and electrical connections. That earlier design required two cables, giving increased potential for system faults in the field. In the TRL5 scanner, we have combined optical and electrical connections into a single, standard cable integrating 8 optical fibres and 2 electrical wires. This required implementation of a system known as data-over-power, so that our system could both provide power and electrical communications between the control unit and the handpiece using only 2 electrical wires. This redesign has substantially simplified connecting and changing the scanning handpiece while in the field.
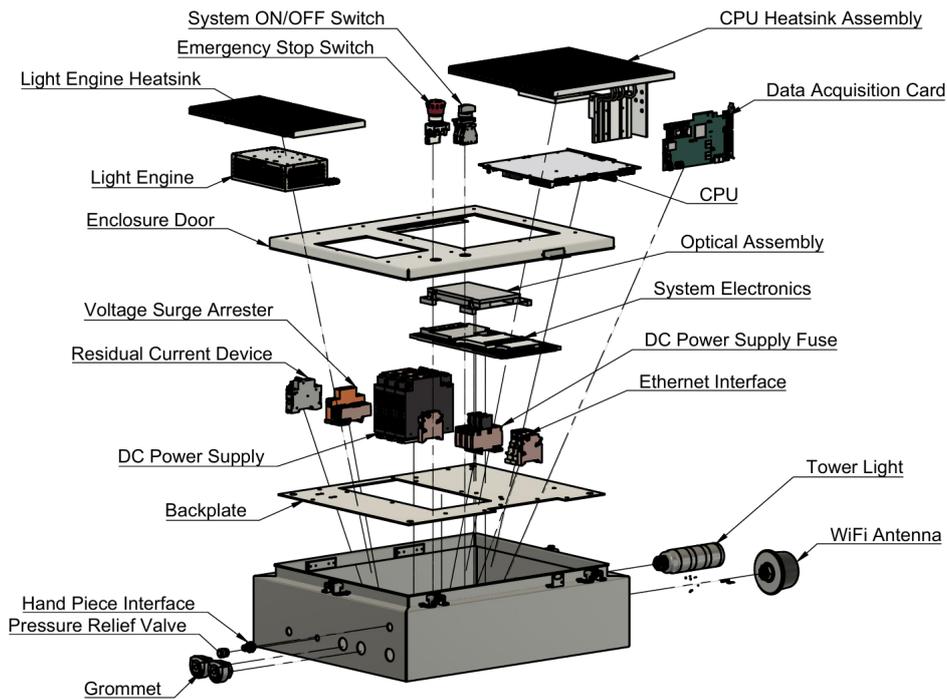
Figure 3. Exploded engineering view of Control unit.

3.2 Software development

Because of their increased muscle mass in comparison to lamb, beef carcases generate larger data sets than lamb carcases. To process these scans, we have developed an artificial neural network based on a Feature Pyramid Network. This 5-layer pyramid network had 6.3 million parameters and was implemented using the MobileOne S0 encoder, which provided a good trade-off of high accuracy and rapid computation. Input to the neural network is an image of size 8,960 x 224 pixels. The network was initially trained on 14,223 manually labelled B-scans of lamb muscle, taken across several sites. We have augmented the training with an additional 557 B-scans acquired on hot beef carcases to account for the tissue structure of beef.

3.3 Feasibility study

To assess the feasibility of this scanner to estimate IMF% in a hot beef carcase, we collaborated with the NSW Department of Primary Industries to acquire data from the Southern Multibreed herd. Scans were acquired on 100 hot beef carcases at Casino, NSW in February 2025, and correlated against a chemical gold-standard measurement of IMF%.

4. Results

4.1 Feasibility Study

An example of a beef scan is shown in Figure 4. The top panel shows the raw, unprocessed optical scan of the beef muscle. This image visualises the tissue structure along the needle trajectory as the handpiece needles are moved through the muscle.

The second panel show areas of intramuscular fat. Intramuscular fat has a characteristic texture that differentiates it from muscle fibres. These areas have been automatically highlighted in yellow using our artificial neural network algorithm. The bottom two panels show zoomed insets from the scan.
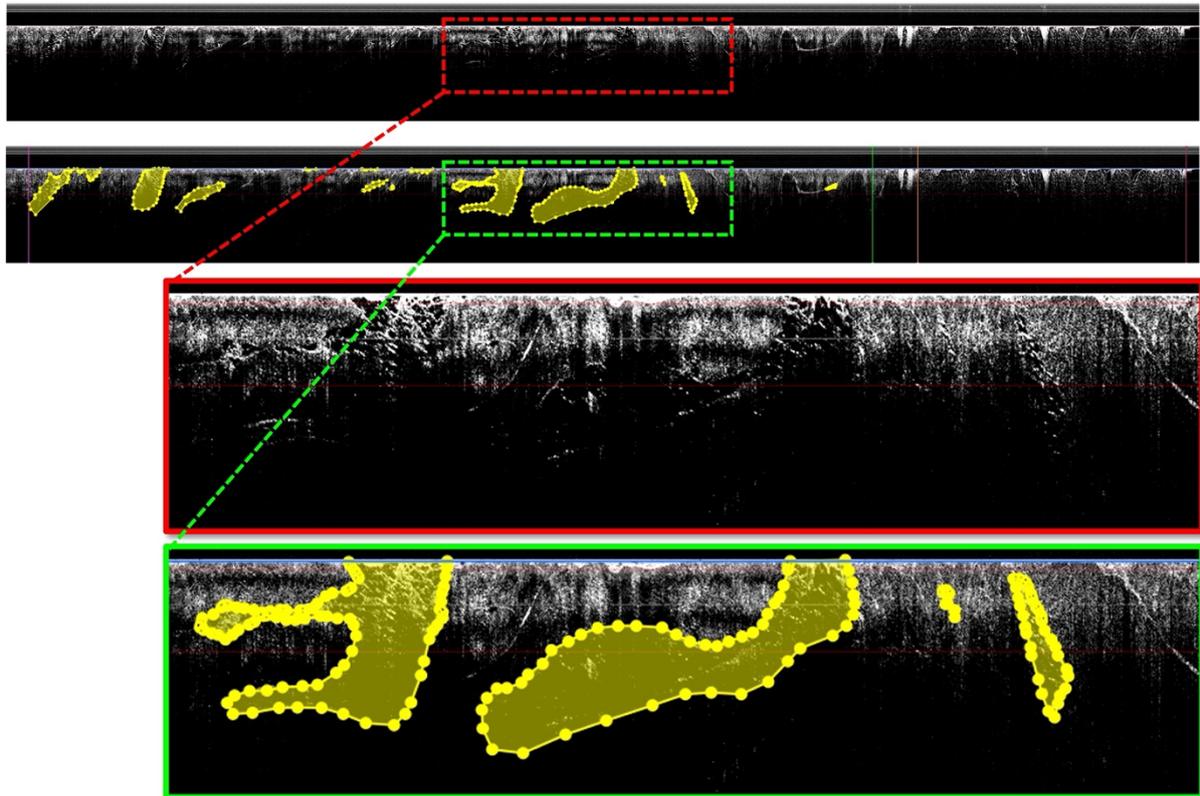

Figure 4. (top row) Optical scan showing muscle from a hot beef carcase. (2nd row) Areas of intramuscular fat automatically identified in yellow. (3rd row) Zoomed inset of optical scan. (4th row) zoomed inset of scan with intramuscular fat identified.

Scans were acquired on 100 hot beef carcases. Each scan took approximately 3 seconds to acquire, and two scans were acquired on each carcase. These scans were analysed using our artificial neural network, providing an estimate of IMF% for each fibre-optic probe. These were then combined to calculate an estimate of IMF% for the carcase. Subsequently, samples of the muscle were extracted for chemical analysis, to provide a gold-standard estimate of the IMF%. These results are shown in Figure 5.
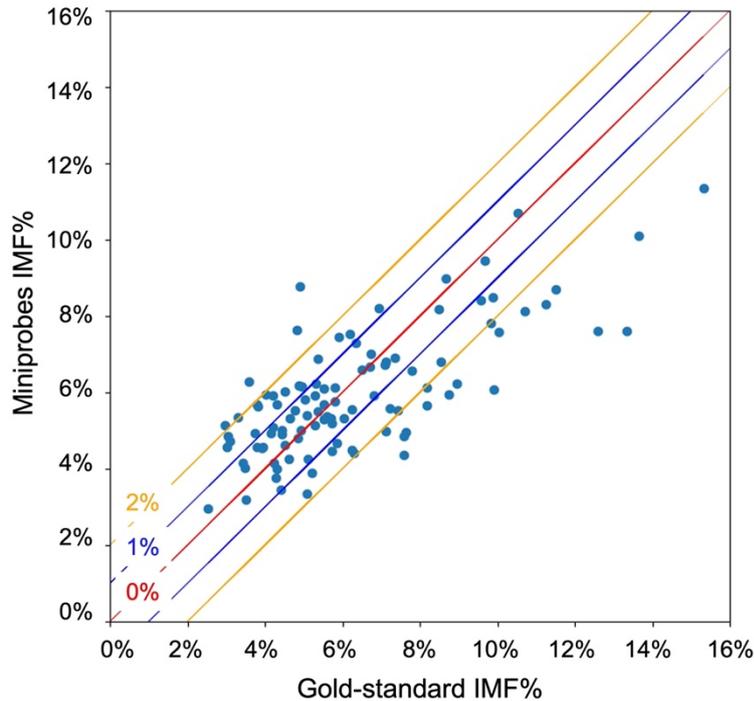
Figure 5. (vertical) IMF% estimates calculated using the Miniprobes optical scanner vs (horizontal) chemical gold-standard measurements obtained on 100 hot beef carcases.

In Figure 5, gold-standard estimates are plotted along the horizontal axis, and our hot carcase estimates are plotted along the vertical axis. The red diagonal line shows 0% error. Points along the blue diagonal line vary from the gold standard value by 1%, and points along the gold diagonal line vary by 2% from the gold-standard.

These results show a good correlation between our hot carcase estimates and the cold-carcase gold-standard measurement. The average absolute error was 1.4%, and the RMSE was 1.8%. The r^2 correlation value was 0.56.

We noted a larger error at higher levels of IMF%. We believe this is because the artificial neural network has been trained on lamb scans, where IMF% values are much lower, typically (2% - 6%). We included a small amount of beef training data (557 scans). However, the majority of our training data was acquired on lamb carcases (14,7779 scans). We expected the accuracy of this scanner to significantly improve with the inclusion of more beef training data.

5. Conclusion

5.1 Key findings

This project has established the feasibility of adapting this technology from use in lamb to hot beef carcases. We have demonstrated that the handpiece can be adapted for use in beef carcases and have shown good correlation with gold-standard estimates of IMF%. We have also identified key areas for improvement. In particular we have identified a need for further training data from beef carcases. The current algorithms are predominantly trained to identify intramuscular fat in lamb carcases, which

have a much lower range of intramuscular fat. Given these improvements, we believe that this scanner will offer a practical tool for beef processors to measure IMF% on hot beef carcases.

5.2 Benefits to industry

We have identified two commercial areas where our device has potential to yield value to the Beef Industry.

1. Improved processor boning room efficiencies

Meat processing is separated into two stages: Stage 1. Initial processing (e.g. skin/offal removal) and chilling; Stage 2. Boning, cutting and packaging. Sorting according to quality is highly efficient prior to chilling as carcases can be arranged into different chillers based on meat quality grade. However, current quality assessment methods (e.g. MSA) can only be applied once the meat has been chilled, allowing the intramuscular fat to become visible to the human eye. Meat processing plants are not set-up to efficiently sort carcases as they leave the chiller and enter the complicated workflow of the boning room. Based on the analysis presented by Griffith et al. [5], we assume an increase in productivity of 1.1% per person per day due to quality grading immediately after slaughter. This would yield a reduction in beef processing costs of $2.43 per head, on a $220/head cost. With 8.7 million head of cattle processed annually, this provides a saving for the beef industry of $21.4mil per year.

2. Reduced wastage costs

In the Australian beef industry, wastage costs an estimated $130 million/year from producers supplying cattle not meeting customer requirements [6]. This arises from a mismatch in two factors: meat-eating quality and lean meat yield. Objective measurement of meat-eating quality immediately after slaughter will help processors to optimise the supply of quality grades between multiple consumers. It will also provide feedback to cattle producers on the impact of nutrition and rearing practices. Assuming rapid assessment of meat-eating quality supports a 20% reduction in wastage, this provides a potential value of $26mil per year in reduced wastage.

6. Future research and recommendations

Based on the successful outcome of this project, we recommend a follow-on project to fully adapt this scanning technology for use in a beef processing plant. This project would include acquiring additional training data for the analysis algorithms and developing manufacturing processes for the beef-specific handpiece with longer needles. Funding for this project has already been secured through a Commonwealth Department of Industry CRC-P funding grant with MLA support (V.TEC.2600).

6.1 Milestone summary

All final milestones for this project have been successfully completed:

Task:

- *Trial scans completed on minimum of at least 100 carcases.*
- *Validate accuracy of measurement of IMF*
- *Detailed analyses of the accuracy of the system to measure IMF%*

A feasibility was completed on 100 beef carcases from the Southern Multibreed project. Estimates of IMF% were validated against a chemical gold-standard measurement. The average absolute error was 1.4%, and the RMSE was 1.8%. The r^2 correlation value was 0.56.

Task:

- *Recommendations for a Phase 2 project detailed.*
- *Outline of plan to attract follow-on funding*

A phase 2 project has been defined to complete the translation of this technology for use in the beef industry. This has secured funding with a Commonwealth Dept. Industry CRC-P grant, with support from MLA (V.TEC.2600).

Task

- Review and update Miniprobes and University of Adelaide licenses with IP developed during project

To ensure the efficient translation of any intellectual property arising from this project, we have reviewed the current IP agreements between Meat & Livestock Australia, The University of Adelaide, and Miniprobes Pty Ltd. These have been revised to include IP arising from this project.

7. References

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