Final report

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Implantable RFID for cattle – commercial supply chain trials

Final Report

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Table of Abbreviations

Agtech	Agtech is used as a generic term for digital technologies that are being developed and commercialised for adoption in agriculture. Agtech is the foundation of the digitalisation of agriculture.
ADAS Ltd	A private agriculture and environment consultancy company in the UK.
APVMA	Australian Pesticides and Veterinary Medicines Authority
CCA	Cattle Council of Australia
DEFRA	Department for Environment, Food and Rural Affairs. Federal Government agency in the UK.
EU	European Union
EID	Electronic identification
EUCAS	The European Union Cattle Accreditation Scheme is a national animal production scheme that guarantees full traceability of all animals through the National Livestock Identification System (NLIS). EUCAS allows Australia to meet EU market requirements for beef by segregating cattle that have never been treated with HGPs.
FDX	Full Duplex communications protocol dictates how information is transferred between the reader and the tag. With an FDX protocol, information can be transmitted from tag to reader and from reader to tag simultaneously. (see HDX)
HDX	Half Duplex communications protocol dictates how information is transferred between the reader and the tag. With HDX protocol, information can be transmitted from tag to reader and from reader to tag but not at the same time. (see FDX)
HGP	Hormonal growth promotant
ISC	Integrity Systems Company
ISO	International Standards Organisation
ICAR	International Committee for Animal Recording
LPA	Livestock Production Assurance
LF	Low frequency
MSA	Meat Standards Australia
MLA	Meat and Livestock Australia

NRS	National Residue Survey
PIT	Passive Integrated Transponder
NLIS	National Livestock Identification System
NVD	National vendor declaration
OHS	Occupational health and safety
RDC	Research & development corporation
RFID	Radio frequency identification
ROI	Return on Investment

Abstract

The purpose of this study was to investigate the desirability and feasibility of an implantable plastic RFID Passive Integrated Transponders (PIT device - tracking tags that do not require power; instead, they have an internal microchip that is activated when it passes close to a special antenna) concept for the purpose of animal identification in cattle in Australia. The focus was on identifying and overcoming barriers to adoption, such as ensuring the device could be reliably implanted, retained, and read by existing RFID readers, and easily removed when needed. The PIT concept addresses the issue of RFID tag loss with external ear tags. This research tested plastic PIT devices in cattle for over a year in both northern and southern Australian production systems.

The trials were conducted on cattle aged 6 to 24 months, and included data collection on the implantation, retention, performance, and removal of the PIT devices in real-world conditions. The study also explored both the technical and operational challenges associated with the concept by the execution of field trials and engagement with the beef supply chain, in particular meat processors. Key insights were generated regarding the articulation of barriers to commercial adoption. Significant progress was made on several of these barriers, whilst others currently remain unsolved. This work offers considerable benefits to various stakeholders within the Australia red meat supply chain (particularly beef) concerned with improving their ability to reliably identify animals and record data by utilising sub-cutaneous devices for future on-farm efficiency improvements.

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Executive summary

Background

The National Livestock Identification System (NLIS) is Australia's system for the identification and traceability of cattle, sheep and goats and is designed to protect these industries from biosecurity and food safety threats, as well as access international trade markets. Animal identification through the application of an electronic RFID tag (predominantly an external ear tag) to livestock is a critical element of a functional system. When ear tags are lost, damaged, or non-functional, animal traceability data is lost. This project was designed to investigate the use of a plastic PIT tag as a "tag for life" and a potential alternative method for electronically tagging cattle in Australia.

This research aimed to identify and evaluate the desirability and feasibility of a prototype plastic PIT tag in a commercial setting within the Australian cattle industry. The concept of a "tag for life" is highly desirable within the beef industry, however any candidate device would need evidence to ensure that it could be reliably implanted or affixed, retained, read by existing RFID readers, and easily removed when needed. These were the key areas of investigation of this research project and were identified as key adoption challenges.

The research engaged the entire supply chain, with a particular focus on processors, who play a critical role in the removal of electronic ID (EID) devices and are the gateway to domestic and foreign markets. This research was not part of a formal device certification trials, however, the field trials were designed after consideration of the current National Livestock Identification System (NLIS) certification processes. The data and insights gained from this research demonstrate that several technological barriers to implanted PIT tag have been solved, while others will require further work to overcome.

Objectives

The objectives were as follows.

1. investigate the potential of plastic PIT tags in cattle in commercial enterprises by conducting long-term field trials on a prototype device.
2. measure the retention and performance of the implanted PIT tags in different on-farm scenarios.
3. identify and investigate any supply chain operational issues that may arise, including further investigation into challenges identified for commercial adoption.
4. explore tooling requirements for the successful implantation and removal of PIT tags.

Methodology

To achieve the objectives, the research team conducted two field trials in northern and southern beef operations in Australia. A prototype 22 mm plastic PIT tag was implanted in 333 cattle across the sites. Over 12 months, the team measured the tags' retention and performance, followed by on-site removal. The collected data included:

1. The implantation process and tag retention over time.
2. The readability of the PIT tag transponder.
3. The welfare of the trial animals.
4. The PIT tag removal process and the need for additional equipment.
5. The design and testing of a prototype PIT tag removal device.

This data was used to evaluate the ease of application, removal, and performance of the prototype PIT tag, with the expectation that further development is needed for improvement.

Industry engagement was a key component, with over 30 interviews across the supply chain and four processor site visits and workshops. These interactions explored industry perspectives on the PIT tag concept, identified barriers to adoption, and discussed potential solutions. The project also developed and tested a prototype PIT tag removal tool to ensure the devices could be safely and efficiently removed at processing plants.

The findings provide valuable insights for industry discussions on alternative animal identification methods and future R&D efforts for PIT tag technology.

Results and key findings

Field trials

1) Plastic 22mm long PIT tags can reliably be implanted in the middle back of a bovine ear using a single shot applicator device. Best results are achieved when cattle do not have previous tags or injury to the implant location. Careful adherence to the implantation procedure is essential. The development of a multi-shot device for this purpose is achievable since there are currently commercially available devices used in analogous farming circumstances.
2) PIT tag retention after being implanted for at least 12 months was 96.3% at the representative northern beef production operation and 76.8% at the southern beef production operation. Contributing factors to the variation in retention were operator or application procedure variance, and breed or geographical variance.
3) PIT tag readability was inconsistent with a wand reader due to some combination of transponder unreliability and variation between different readers. PIT tag readability after at least 6 months was around 91% (Aleis 7020 Stocky reader) at the representative northern beef

production operation and between 99.5% and 50.9%, for Fofia PT280 and Aleis 7020 Stocky readers respectively, at the southern beef production operation.

4) PIT tag retention and migration have the potential to be adequately controlled or eliminated by the careful design of the PIT tag (materials and design), the applicator, and the application procedure. Improvements in these elements based on information contained in this report are expected to translate into higher PIT tag retention rates and better consistency between geographical sites.

Supply chain engagements

1) The supply chain had previously identified 5 key challenges to be addressed before they would consider the adoption of a plastic PIT tag:
    1. Application: How will the PIT tag be implanted efficiently and effectively?
    2. Retention: How reliable is the PIT tag regarding dropout, migration, and infection?
    3. Readability: How well does the PIT tag read?
    4. Device identification: How does the supply chain know a PIT tag is being used?
    5. Device end-of-life: How can the PIT tag be removed efficiently, effectively and safely?
2) For most of the key challenges identified, there are also legislative and policy hurdles that specify minimum levels of performance of devices used in animal identification in Australia. Performance at these levels must be demonstrated to relevant authorities for accreditation and commercial sale.
3) A PIT tag has the potential to be reliably removed at a processor facility by an inexpensive, effective and safe pneumatic or hydraulic-powered tool. Further work is required to refine the prototype designed in this project and manufacture the tool. The location of PIT tag removal is best determined by each processing facility based on specific operational needs.
4) A visual tag is essential to indicate the presence of an implanted PIT tag. Visual tags used in this study demonstrated 100% retention, however, the combined cost of the visual tag and PIT tag must be competitive with existing ear tags to encourage adoption.
5) PIT tags can be viewed as a delivery vessel for a range of different technologies that may be useful to the Australian livestock sector to improve its performance in the areas of animal welfare and monitoring, environmental, and on-farm management performance.

Benefits to industry

A prototype plastic PIT tag has been developed and trialled in cattle to investigate the performance as an alternative animal identification device. Although the device is not currently suitable for immediate adoption, important information and insights have been generated in this research that are relevant to beef, sheep and goat producers. Device manufacturers and technologists can also draw important insights from this work to help identify and overcome key issues for the future development of any implantable device intended for commercial use in a livestock setting in Australia.

The intrinsic benefit of a "tag for life" is clear and the support indicated from our industry engagement shows there is a strong desire for improvement in animal identification and data collection within the Australian cattle industry.

Future research and recommendations

Deep engagement by technology owners and device manufacturers is needed to address the technical issues identified in this research, whereby these groups can conduct their own commercial diligence on the "tag for life" concept and the desirability of beef producers and regulators can be assessed. Key beef supply chain members, such as vertically integrated businesses and dominant market players, should form partnerships with technology providers to refine and develop the necessary hardware and software. Peak bodies and research organisations, like MLA, play a crucial role by funding foundational research that lays the groundwork for industry advancements, providing funding mechanisms and governance to foster industry-technology partnerships. Regulators and government agencies should review and update standards to promote advancements aligned with strategic industry goals. All supply chain participants must be open to adopting better farming practices and trialling new options in development and new to the market. It is important that new concepts are connected to the potential users to generate a useful R&D plan, and decision-makers are patient and have reasonable expectations of the new product development process.

1 Background

1.1 Field trials

Australia's reputation as a producer of clean and safe beef products relies on the lifetime traceability of its cattle. However, issues with physical tags—such as lost, unreadable, or damaged tags—threaten this traceability. The project "V.RDA.0002 - Assessing the Feasibility of an Implantable RFID" engaged the Australian beef supply chain and confirmed that "lost" electronic tags are a significant concern for some stakeholders, with tag replacement costs estimated at around $10 million annually [1]. This problem isn't unique to Australia; a 2023 investigation by OSPRI New Zealand found that tag retention is a major concern for farmers, with tags often falling out earlier than expected due to factors like fencing wire or scrub getting caught behind the tags [31].

In the feasibility study supported by the Integrity System Company, Australian beef supply chain stakeholders were consulted about using a plastic passive injectable transponder (PIT tag) as an alternative identification method. The consultations emphasized the need for proper site selection, implantation, and removal procedures, along with clear communication of the implant's presence (through earmarks, visual marker tags, or other means). Additionally, the alternative identification device must demonstrate high performance in terms of readability, retention, and anti-migration, which would require field trials to assess these parameters effectively.

Previous trials using glass PIT tags for livestock identification have faced challenges related to device recovery and food safety, limiting their widespread use in livestock applications. However, these earlier efforts provided valuable insights for designing long-term trials using plastic PIT tags in Australian livestock conditions. Research by Klindworth et al. [32], Conill et al. [33], and Fallon et al. [34] indicated a preference for the ear as the injection site, with the middle back of the ear being ideal due to its protection between veins, cartilage, and fat deposits. This site was associated with high recovery rates during processing and minimal impact on animal welfare. Conill et al. [33] also contributed detailed injection procedures aimed at promoting wound healing and closure. Short-term field trials (90 and 140 days) from previous studies [27] confirmed that PIT tags (22 and 32 mm, both Poly-dopamine (PDA) coated and uncoated) implanted in the middle-back of the ear were well retained, with low or no device migration, and posed minimal risk to animal welfare.

Based on these previous studies, this current project was established to collect long-term performance data on a prototype 22mm long plastic PIT in commercial supply chains and further explore the needs and adoption barriers across the supply chain. New areas of investigation not previously reported in the literature, included, but was not limited to;

1. The formation of a detailed PIT tag implantation procedure and producer education materials.
2. The implantation of plastic PIT tags in over 300 animals located in representative Northern and Southern commercial beef producing operations in Australia for a period of 12 months.
3. The collection of retention and readability performance data of plastic PIT devices for a period of 12 months.
4. Engagement with 3 major Australian meat processors on-site to investigate and discuss the PIT tag removal process and explore potential commercial barriers.
5. The design and build of a prototype PIT tag removal device.

The main objective of this work was to further explore the feasibility of using PIT tags for animal identification in Australia. This foundational research addresses a problem recognised as important by industry stakeholders and provides critical information for solution providers aiming to develop and test PIT tags for accreditation in Australia. The field trial procedures were aligned with the NLIS RFID Field Trial Protocol, a mandatory step in the accreditation process [2]. The potential market for plastic PIT tags includes producers with cattle aged 6-24 months that have not yet been tagged. In addition to the field trials, the research included supply chain engagement through online surveys and site visits to identify potential operational issues and explore solutions.

The information in this report can assist red meat administrators in evaluating the performance of plastic PIT tags in Australian cattle operations and considering their applicability to other species like sheep and goats. Producers dealing with electronic tag loss can gain insight into the development status and ongoing challenges of plastic PIT tags as an alternative. Device manufacturers are encouraged to review this report to inform their research and development investment plans for the global livestock market.

1.2 Supply chain operational challenges

Stakeholder engagement and short-term field trials from previous research [1] identified five key challenges that needed to be addressed in this study. These challenges guided the design and execution of the two field trials and were central to discussions during industry engagement.

Defining these challenges allowed the project to focus on building a knowledge base for each one, helping to determine whether they could be resolved or might prove intractable. Various factors in the field trials could be adjusted, many of which directly impacted the project's objectives. For example, the success of implanting the prototype PIT tags depended on the tag dimensions, applicator design, and operating procedures—any changes to these variables could lead to different outcomes. Likewise, modifying the PIT tag's design (shape and materials) would affect retention performance, and choosing a different transponder or manufacturer would impact readability.

By making informed decisions based on the best available data, the project successfully implanted cattle with PIT tags and evaluated their performance in long-term field trials. The data collected can be used to refine the technology and make progress in overcoming the known barriers to adoption.

Challenge 1 | Application: How will the PIT tag be implanted efficiently and effectively?
Efficient and effective implantation of RFID devices in cattle is a crucial challenge that requires careful execution to minimize stress and discomfort for the animals while ensuring accuracy and consistency. The implantation process should seamlessly integrate into existing livestock management practices, ideally being quick and easy for on-farm workers to perform. Proper training and standardized protocols are vital to ensure correct implantation, reducing the risk of complications. Additionally, the tools and equipment used must be user-friendly, durable, and designed to prevent injury to both the animals and the operators.

Challenge 2 | Retention: How reliable is the PIT tag regarding dropout, migration, and infection?
"Drop-out" refers to the physical loss of a PIT tag from the application site, which typically occurs shortly after implantation, before the tissue has fully healed, or because of localized infection. According to Section 5.20 of the NLIS RFID Standard, the acceptable device loss rate is less than 3.5% over three years in typical meat, dairy, and feedlot environments. Migration, where a PIT tag moves subcutaneously away from the implantation site to another part of the animal, is another undesirable event. The primary advantage of PIT tags is their potential to provide a permanent, lifelong animal identification solution. Factors influencing retention include the tag's design (size, shape, and physical features), materials (such as polymer composition and coatings), and the implantation equipment and procedure. The PIT tag must be biocompatible enough to minimize infection risk and promote rapid tissue integration. Other studies have noted significant PIT tag migration, which complicates locating, scanning, and removing the devices. For accreditation and commercial use, PIT tags must undergo rigorous testing in various environmental conditions to ensure they can endure farm life, including ear movement, physical impacts, and weather conditions.

Challenge 3 | Readability: How well does the PIT tag read?
The readability of the implanted PIT tag is crucial for accurate and efficient livestock tracking and must meet NLIS standards. The NLIS RFID standard requires a maximum of 0.5% transponder failure over 3 years, with the device to be reliably scanned and read by standard RFID readers used in the industry. The readability must remain consistent over time, regardless of the animal's growth, movement, or environmental conditions. Factors affecting readability include the placement of the PIT tag (its location and orientation relative to a reader), the transponder's performance (power, tuning, and suitable electrical specifications), and its compatibility with different readers. Australia has adopted a half-duplex, low-frequency operating standard for animal identification. Unlike ultra-high frequency (UHF) technology, low-frequency (LF) technology does not include an anti-collision protocol and cannot read multiple devices simultaneously. The presence of more than one LF device in proximity may result in a non-read.

Challenge 4 | Device identification: How does the supply chain know a PIT tag is being used?
All stakeholders in the supply chain must be aware of the presence of an implantable device in the animal. Currently, section 5.14 of the NLIS RFID Standard provides instruction for the use of an internal RFID device, requiring that it must also be supplied with a large visual ear tag, displaying the NLIS logo, NLIS animal identification number, the words “DO NOT REMOVE”, which is applied to indicate the presence of the internal device. Whilst not specified in the current standard, it is likely the word “IMPLANT” will also need to feature on the visual ear tag, as is the case for the use of rumen boluses.

The requirement to also display a visual marker tag when using an implant would appear to diminish a core advantage of the PIT tag concept since visual marker tags presumably present a similar risk of tag loss as external RFID ear tags. Nonetheless, ensuring that the presence of a PIT tag is immediately and unmistakably known by all in the beef supply chain is critical. The commercial use of PIT tags would require regulatory discussion and review, training and education solutions for the beef supply chain (domestic and international markets), to ensure compliance and standardised practices across the industry.

Challenge 5 | Device end-of-life: How can the PIT tag be removed efficiently, effectively and safely?
The process of PIT tag identification and removal at the processor must be achievable consistently, rapidly (within ~20 seconds) and safely by plant operators. Site visits to several major Australian meat processing facilities further highlighted the need for a foolproof method of device identification, as well as the need for equipment to facilitate the PIT device removal. New equipment must be designed to be integrated into existing workflows, without introducing new labour demands. This will involve using purpose-built tools. The location of the PIT tag extraction will likely vary between different processing facilities to fit seamlessly within the different workflow and procedural norms, which are unique to each plant. It is essential that processors can reconcile all recovered PIT tags to ensure exclusion from international HGP-free markets. Finally, considerations should be made for the end-of-life PIT tag disposal, especially if its removal results in a combination of tissue and metal/plastic components.

Figure 1 outlines the impact location in the supply chain of the above-mentioned challenges.

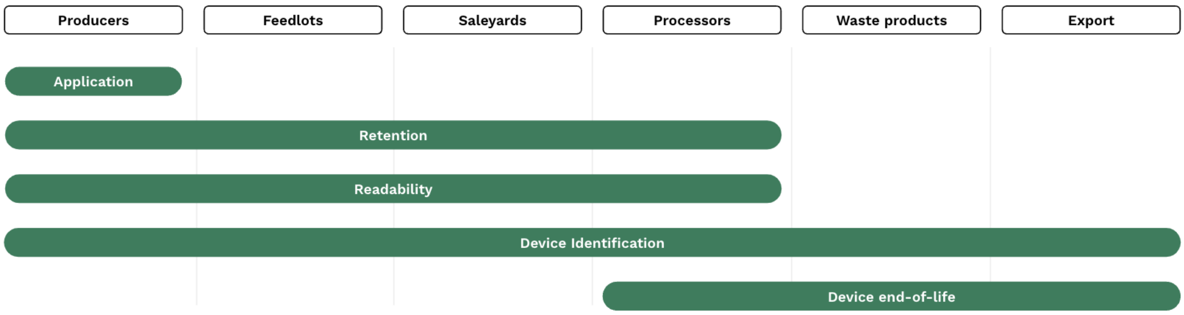

Figure 1- The impact location of the primary challenges to be overcome for the use of PIT tags in the commercial beef supply chain.

The remainder of this report will detail the results of the two field trials, discussing how the PIT tag technology used in this study performed against the five operational challenges. It will also provide guidance for future technology development by incorporating stakeholder perspectives. Additionally, the report will consider both operational and non-operational barriers to technology adoption, using a framework presented by Ball et al. [8], and assess the status of the plastic PIT tag technology used in this study against this framework.

2 Project objectives

2.1 Objectives

The objectives of this project are as follows:

1) to investigate the potential of plastic PIT tags in cattle in commercial enterprises by conducting long-term field trials.
2) to measure the retention and performance of implanted PIT tags
3) to identify and investigate any supply chain operational issues that may arise, including further investigation into the main 5 challenge areas for commercial adoption identified.
4) to explore tooling requirements for the successful implantation and removal of PIT tags.

Two commercial supply chain trials were conducted to test and validate the performance of prototype plastic PIT tags. Since this solution is most suitable for animals that haven't been previously tagged, we selected younger animals from private producers representing Northern and Southern beef operations. The study involved collecting data and assessing the long-term retention and performance of the tags, along with gathering industry feedback on their implantation, use, and removal. The trials focused on addressing five key challenges that must be overcome before adoption. Additionally, a prototype tool was developed and tested to aid in the removal of PIT tags at processing facilities. Based on the findings, insights and recommendations were provided for improving the next iterations of the device design.

3 Methodology and field trial results

This section will summarise the two different trial results and then provide overall learnings and a summary. This section will build on the evidence base for challenge areas 1-4 - application, retention, readability and device identification.

3.1 Trial 1: Jericho QLD

3.1.1 Device implantation details

Table 1. Device Implant Details: Trial 1 Jericho QLD

Device Implant Details: **Trial 1 Jericho QLD**	
Implant date	05/05/2023
Device name	XXXXX 22mm
Species tagged	Charbray Weaners, 5-9 months, Heifers
Production system	Grass-fed beef (certified organic)
No. of animals tagged	110

There were no PIT tag implantation difficulties that resulted in a 'failed' application. Appendix 3 shows minor exceptions experienced with a small number of the devices during the implantation process. A summary of the implantation process includes the following points:

- Pre-implantation, all PIT tags were successfully scanned with a stocky hand-held reader.
- Post-implantation, 30 of 110 (27%) beasts were run past the Datamars TruTest XRP2 panel reader mounted on the opposite side of the crush and all read successfully.
- Several beasts produced significant bleeding at the implantation site in the ear.
- A large earmark (on smaller animals) provided poor implant placement options than normal on 6 beasts (5.5%).
- The average time to tag (apply the PIT tag and a visual marker, then scan) was 20-30 seconds.

3.1.2 Results and observations

Table 2. Jericho PIT retention

	Observation 1 | 8 Months	Observation 2 | 14 Months
Number of animals presented	109[1]	108[2]
With Tag	108 (99.1%)	104 (96.3%)
Without Tag	1 (0.9%)	4 (3.7%)

[1] 1 beast did not present for observation and was consequently excluded from the trial.
[2] 1 beast did not present for observation and was consequently excluded from the trial.

Table 3. Jericho PIT Device Read Performance

	Aleis 7020 Stocky Stick Reader	Secondary Read	Panel
Observation 1 | 6 Months		**Datamars Tru-Test XRS2**	**XRP2**
Number of animals scanned	107	6	108
Positive scan	97 (90.7%)	6 (100%)	105 (97.2%)
Observation 2 | 12 Months			
Number of animals scanned	104	NA	104
Positive scan	82 (78.8%)	NA	45 (43.3%)
Negative scan devices re-scanned upon removal	22/22 (100%)		

Observation Summary

The observational data collection process for the Jericho trial cohort involved a two-day drafting process, where the 110 trial beasts were identified among a larger mob of 1700 beasts of similar age and older. At implantation, the trial cohort beasts were approximately 5-9 months old, presented as healthy and free of obvious disease or infection, and weighed 150-250 kg. At the trial's conclusion, the beasts were up to 24 months old, weighed 400-450 kg, and were in good health. One beast was not present in the larger mob mustered for drafting at observation one and observation 2 and were therefore excluded from the trial. In terms of retention, one device was recorded lost at observation 1 (99.1%), and three devices recorded lost at observation 2 (96.3%). There was only 1 beast (<1%) that recorded notable PIT tag migration of around 30 mm from the original application site.

In terms of device read performance, a fixed panel reader recorded 97.2% scan success in observation 1, and 43.3% success in observation 2. The recommended Aleis Stocky handheld reader recorded positive scans on 90.7% of implanted devices in observation 1, reducing to 78.8% in observation 2. Acceptable handheld reader success was achieved using a Datamars Tru-Test XRS2 model in observation 1 (six reads at 100%).

Retention and migration

A total of 99.1% and 96.3% of devices were retained at observations 1 and 2, respectively. Device retention at this site was promising, even though it was marginally outside the required NLIS standard of performance of 96.5% allowable loss over a 3-year period. Nonetheless, this result is significantly better than glass PIT retention reported in other studies. Increasing the sample size and making further improvements to the PIT tag design and application procedure could conceivably translate into further improvements to meet and exceed retention and anti-migration targets.

Figure 2 shows a typical PIT device implanted, taken during observation 2. Several cases of PIT tag migration of 20-30mm were recorded from the original application site but were within acceptable limits. There were no obvious signs of infection, and all beasts were considered to be in good health.

Figure 2 - Implanted PIT device at Jericho site after 14 months.

Transponder reliability and readability

In terms of device performance, a fixed panel reader recorded 97.2% scan success in observation 1, reducing to 43.3% success in observation 2. The recommended Aleis Stocky handheld reader recorded positive scans on 90.7% of implanted devices in observation 1, reducing to 78.8% in observation 2. These results indicate a degradation in the performance of the transponder over time, and are outside the NLIS acceptable limits on transponder performance of 0.5% failure over a 3 year period. The recorded transponder performance warrants further technical investigation to determine the reasons for the degraded performance over time.

During observation one reads, the trial team experimented with a Datamars Tru-Test XRS2 handheld reader to investigate whether non-reads could be related to the recommended reader. Six of the implanted PIT devices that failed to record a successful scan using the Aleis reader, were rescanned successfully using the Datamars reader. Furthermore, all non-scan devices recorded 100% scan success post-removal, using the Aleis handheld reader. This result may indicate a technical issue with the recommended handheld reader that warrants further investigation.

Overall, the transponder performance at this site was poor with fixed panel infrastructure, but good using a Datamars Tru-Test XRS2 handheld reader, albeit with a reduced sample number. The scanning performance of implanted devices using the recommended Aleis reader was poor. It is clear that further investigation is required to determine the cause of the performance issues related to the transponder, which are beyond the scope of this report. As part of further work, the relationship between transponder/reader specifications and the effect on performance is important to understand. The test conditions such as the position and orientation of the PIT tag in relation to the reader is also known to play a role in the observed read range performance of RFID systems.

3.2 Trial 2: Esperance WA

3.2.1 Device implantation details

Table 4. Device Implant Details: Trial 2 Esperance WA

Device Implant Details: **Trial 2 Esperance WA**

Implant date	26/05/2023
Device name	XXXXX 22 mm
Species tagged	Angus Weaners, < 2 years old, Heifers
Production system	Grass-fed beef
No. of animals tagged	223

There were no PIT tag implantation difficulties that resulted in a 'failed' application. Appendix 5 shows minor exceptions experienced with a small number of the devices during the implantation process. A summary of the implantation process includes the following points:

- 23 PIT devices (10.3%) were applied to the ⅓ of the ear nearest the head due to pre-existing tags in the desired mid-ear position.
- This trial cohort had two separate EIDs (pre-existing external ear tag and the trial implant). The respective state government agency did not allow the removal of the pre-existing tag, which was also later identified as the likely source of the majority of no-scans associated with the Aleis reader.
- The Aleis reader supplied was considered unsuitable for trial work at this site since it was not equipped with a visual screen indicating animal ID.
- The average time to tag (apply the PIT tag and a visual marker, then scan) was 20-30 seconds.
- A different operator applied the PIT tags at this trial location to explore the robustness of the trial implantation procedure and the human skill requirement for successful implantation.

3.2.2 Results and observations

Two in-field data observations were collected at eight months (observation 1) and 12 months (observation 2) on beasts post PIT device implantation.

Table 5. Esperance PIT retention

	Observation 1 | 8 months	Observation 2 | 12 months
Number of animals presented	215[3]	211[4]
With Tag	183 (85.1%)	175 (82.9%)
Without Tag	32 (14.9%)	36 (17.1%)

Table 6. Esperance PIT Device Read Performance

	Fofia PT280 Stick Reader	Aleis 7020 Stocky Stick Reader	Panel
Observation 1			
Number of animals	183	173[5]	NA

3 8 animals did not present for observation and were consequently excluded from the trial.
4 4 animals did not present for observation and were consequently excluded from the trial.
5 For 10 animals, it was unknown which EID was scanned, hence they were removed from the data set.

scanned			
Positive scan	182 (99.5%)	88 (50.9%)	NA
Observation 2[6]			
Number of animals scanned	179	179	NA
Positive scan	179 (100%)	178 (99.4%)	NA

Observation Summary

The observational data collection process for the Esperance trial cohort involved a one-day drafting process of a single mob of 223 beasts. At implantation, the trial cohort beasts were 18-24 months old, presented as healthy and free of obvious disease or infection, and weighed 200-280 kg. The trial was concluded promptly at 12 months duration due to farm operational issues, with all devices being removed on-site. Eight beasts were not present for drafting at observation one and four at observation two and were therefore excluded from the trial. In terms of retention, 14.9% of devices were recorded lost at observation 1, rising to 17.1% devices recorded lost at observation 2. Evidence suggested that the lost PIT tags had been ejected from the application hole. There were several cases (<10) of PIT tag migration of 20-30 mm from the original application site but were within acceptable limits. A panel reader was not available at this trial site, and all readability measurements were taken with either the recommended Aleis Stocky or Fofia PT280 stick reader. The Fofia reader recorded a higher read rate than the Aleis reader at observation 1 (99.5% vs 50.9%, respectively), due to interference caused by the presence of two EID devices, which is discussed in more detail elsewhere. Observation 2 tag reads were conducted post device removal, where the Fofia and Aleis stick readers both recorded high read rates (100% vs 99.4%, respectively).

Retention and migration

A total of 85.1% and 82.9% of devices were retained at observations 1 and 2, respectively. Device retention at this site was poor, and well outside the required NLIS standard of performance of 96.5% allowable loss over a 3-year period. The majority of PIT tag loss occurred within the first 6 months and supports the theory that these losses likely occurred within hours of days after implantation. PIT tags in the two trial sites were implanted by different operators deliberately to explore the robustness of the current implantation procedure for farm workers with varied degrees of pre-existing skill and experience in using HGPs or similar implants. It is possible that using a different operator to implant the PIT tags, physical and behavioural differences in cattle breeds, or environmental factors associated with the different geographical locations of the trial sites accounted for the variance in the retention performance of PIT tags. These factors will be explored in more detail in the following sections.

Considering that the Jericho site recorded good device retention (>96%) for the trial duration, it appears likely that an acceptable level of PIT device retention performance is achievable with further development. The areas for future investigation to improve device retention should focus on fine-tuning the operator implant procedure and education, fine-tuning or developing tools to make the application process easier, and understanding the effect of different breeds, and hence the effect of varied ear characteristics, on PIT device retention success.

6 All PIT devices were scanned post removal from animals in Observation 2 only.

There were several cases (<10) of PIT tag migration of 20-30 mm, although migration distance was estimated based on observing the initial application wound site. In all cases, PIT tag migration occurred towards the head of the animal (butt of the ear). None of the devices had migrated to areas outside the animals ear. Furthermore, due to the complication presented by the presence of pre-existing tags (electronic and visual) in the target application site, some of the PIT tags had been applied close to the butt of the ear from the outset. This application position is not ideal due to its proximity to the head of the animal, and supports an approach of implanting younger beasts, which are less likely to have any pre-existing tags.

Transponder reliability and readability
A total of 99.5% (Fofia PT280) and 50.9% (Aleis Stocky) of implanted PIT devices could be read at observation 1. As noted during the implantation procedure, the recommended Aleis Stocky stick reader was not suitable for the task due to interference caused by the presence of a secondary EID. The cause of this poor performance was, in summary, the higher operating power of the Aleis scanner compared to the Fofia device, picking up the secondary EID, which presents as a "no scan" due to the lack of anti-collision protocol in the LF frequency bandwidth. This will be further discussed in section 3.3.3. Observation 2 read performance data was less useful since devices were required to be removed prior to scanning due to farm operational issues. Both handheld readers recorded over 99% read performance in the laboratory, indicating at least some degree of electrical functionality of the PIT devices after 12 months.

4. Results – Industry engagement and commercial considerations

Stakeholder engagement activities were conducted to identify and investigate potential operational barriers to the adoption of PIT tags throughout the supply chain. The insights gained from these activities also helped identify possible solutions to these challenges and can provide guidance for developing future communication and extension strategies.

Building on previous supply chain engagement [1], this current effort aimed to further explore operational and commercial issues. Interviews were conducted in person, over the phone, or via video conference in casual 30-60 minute sessions. The primary focus was on plant operations, regulatory compliance, market access, and the need for ongoing involvement and communication. Meat processors were the key stakeholders targeted due to their crucial role in using and removing implanted tags. The interviews were analysed to identify key themes and potential solutions to the issues raised. Information from the field trials is also included in this section to provide an update on the technical progress made in addressing specific challenges.

Details of the individuals interviewed and the discovery workshop activities at processor facilities are listed in Appendix 6.

Challenge 1: Application: Can the PIT tag be implanted efficiently and effectively?

Human Considerations - The current combination of PIT tag and single shot applicator can be used by someone skilled in HGP application. The physical demands and skill requirement to implant the PIT tags was not onerous and can be readily learnt by livestock workers. Past research on the implantation procedure concluded that best results were achieved when PIT tags were applied to the middle ⅓ of the ear, and when the smallest possible "pocket" was created during the injection, which reduces the potential movement of the PIT tag subcutaneously [4]. Variability in the size of the pocket formation during implantation may have contributed to the different retention performance between the trial sites. The presence of ear damage and pre-existing tags in the target implantation zone may have also contributed to reduced PIT tag retention. These learnings should be incorporated into additional application procedure notes and become well-practised by technology users. No formal educational requirements, such as those of a veterinarian, are necessary for the PIT tag application procedure.

PIT tag applicator design - Tagging each animal (including applying the PIT tag and visual marker, then scanning) took 20-40 seconds, while loading and securing the next animal in the crush also took 20-30 seconds at the two trial sites. The duration of these procedures depends on the quality of the facilities, with better equipment generally making the process simpler and faster. A head bale and lift are highly recommended for the implantation process, especially when tagging many animals. Despite the lack of a head lift at the Esperance site, the trial team successfully implanted all PIT tags. The design of the applicator significantly affects the speed and efficiency of implantation. A multi-shot applicator, such as those in the Elanco[7] range, could be a valuable feature for potential customers. Improvements to the application hardware would make additional improvements to the tagging time mentioned above. A commercially ready PIT tag implantation process is expected to be similar in efficiency to current external ear tagging methods.

[7] Elanco offers a range of implantables under the brands Component, Encore, and Compudose.

BLUE COMPONENT EZ® GUN

Component® Implants				
IMPLANT	**INGREDIENTS**	**DOSAGE (MG)**	**INDICATIONS**	**ESTIMATED PAYOUT PERIOD**
Component E-C (progesterone and estradiol benzoate implants)	Progesterone Estradiol benzoate	100 10	Beef calves 45 days of age and older and weighing up to 400 lbs.	100–140 days
Component E-C with Tylan®* (progesterone and estradiol benzoate and tylosin tartrate implants)	Estradiol benzoate Progesterone Tylosin tartrate	10 100 29	Beef calves 45 days of age and older and weighing up to 400 lbs.	100–140 days
Component TE-G (trenbolone acetate and estradiol implants)	Trenbolone acetate Estradiol	40 8	Growing beef steers and heifers on pasture (stocker, feeder and slaughter)	100–140 days
Component TE-G with Tylan* (trenbolone acetate and estradiol and tylosin tartrate implants)	Estradiol Trenbolone acetate Tylosin tartrate	8 40 29	Growing beef steers and heifers on pasture (stocker, feeder and slaughter)	100–140 days
Component TE-IH with Tylan* (trenbolone acetate and estradiol and tylosin tartrate implants)	Trenbolone acetate Estradiol Tylosin tartrate	80 8 29	Growing beef heifers fed in confinement for slaughter	100–140 days
Component TE-IS with Tylan* (trenbolone acetate and estradiol and tylosin tartrate implants)	Trenbolone acetate Estradiol Tylosin tartrate	80 16 29	Growing beef steers fed in confinement for slaughter	100–140 days
Component TE-200 with Tylan* (trenbolone acetate and estradiol and tylosin tartrate implants)	Trenbolone acetate Estradiol Tylosin tartrate	200 20 29	Growing beef steers and heifers fed in confinement for slaughter	100–140 days

COMPONENT 200T IMPLANTER®

*CAUTION: Federal law restricts this drug to use by or on the order of a licensed veterinarian.

COMPUDOSE®/ ENCORE® IMPLANTER

Long-Acting Implants				
PRODUCT	**INGREDIENTS**	**DOSAGE (MG)**	**INDICATIONS**	**ESTIMATED PAYOUT PERIOD**
Compudose	Estradiol	25.7	Suckling calves and stocker steers	170–200 days
Encore	Estradiol	43.9	Suckling calves and stocker steers	350–400 days

Figure 3 - Elanco range of implants under the commercial brands of Component, Encore, and Compudose used for animal health and growth purposes.

Challenge 2: PIT tag retention and migration

Figure 4 shows the PIT tag retention for the two trial sites, with the northern beef production operation recording a PIT tag retention of 96.3% (sample size 108) and the southern beef production operation recording 76.8% (sample size 211), at the conclusion of the trials.

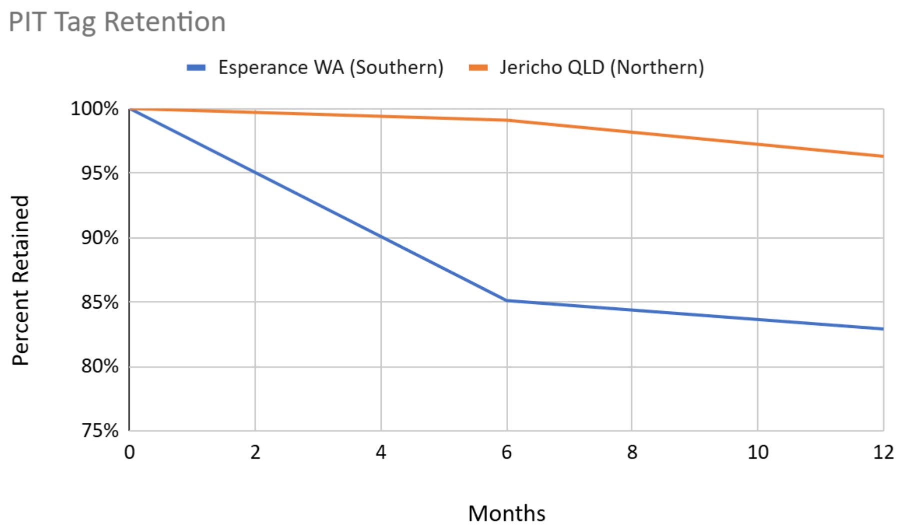

Figure 4- PIT tag retention for the two trial sites

Trial Site Conditions - The Bos Taurus cattle at the Southern site were approximately 24 months old at the time of implantation and already had an existing EID. Their ear condition was generally good, although some animals had multiple visual tags, with some located at the ideal implantation site in the middle third of the ear. While no existing tags prevented PIT tag implantation, about 10% of the PIT tags were implanted in the third of the ear closest to the head (butt). Regarding temperament, the Southern cattle were described by the cattle owner as "a bit reactive" during implantation, but they settled quickly once returned to the paddock. The on-farm infrastructure was basic and not ideal for securing the animals properly during the procedure.

In contrast, the Northern trial site involved younger Charbray weaners, aged 5–9 months. These animals did not have a secondary EID, although a large earmark located in the middle third of the ear required implantation at the butt of the ear in 5.5% of cases. The Northern site had superior farm infrastructure, including a head lift that facilitated the implantation process. After implantation, the Southern site cattle were rotated through paddocks that had previously been used for forestry, with one containing coppice that may have been used by cattle for ear rubbing, potentially contributing to some PIT tag losses, though this was not observed. At the Northern site, the cattle roamed freely in large, semi-arid paddocks in central western uplands. The terrain was mostly flat, with patches of regrowth including turpentine, brigalow, and other scrub covering 60% of the open western downs areas. The cattle grazed on buffel grass in cell grazing systems with mob sizes of 1,000-2,000 head, using centrally located reticulated water points. The area had long-term organic certification, with summer parasite loads primarily consisting of buffalo flies (sometimes up to 100 per side), while being tick-free with minimal winter parasite issues.

PIT tag design features - Future iterations of PIT tags can be enhanced to improve performance as an animal identification tool by modifying design features such as shape and coatings. The PIT tags used in this trial lacked coatings or surface modifications. Previous studies [1] have explored the feasibility of PIT tags in cattle and addressed issues like tag migration [4, 27-30]. These studies found that applying a polydopamine (pDA) coating to the PIT tag's surface significantly improved retention and reduced the risk of migration and infection. pDA-coated PIT tags (22mm and 32mm) adhered much better to tissue, forming a tighter capsule around the tags.

The PIT tags used in this trial had a rounded leading edge and a blunt, flat trailing end, designed by XXXXX to prevent the tag from moving backward and exiting through the entry site. Observations from the Esperance site indicated that while the blunt end effectively limited backward movement, the rounded leading edge allowed the tag to move forward within the injection pocket due to reduced friction. As a result, some tags were observed migrating forward toward the ear's butt. Although none of the migrations measured at 6 or 12 months exceeded the project's maximum allowable range of 30mm, eliminating any migration is preferable, especially for large-scale use.

The importance of pocket formation - The UQ reports [27-30] also highlighted the importance of creating the smallest possible initial "pocket" during implantation to ensure a strong "tissue-tag" bond and prevent migration. PIT tags implanted in the inner third of the ear (butt) had larger pockets, likely due to increased tag movement at the cartilage ring/muscle interface compared to the preferred middle third of the ear. The reports concluded that the size of the initial pocket and the implantation location (middle third is optimal) were crucial factors influencing tag retention and migration.

It is also important to consider potential market access issues when using synthetic coatings. Coated PIT tags were not used in this study due to concerns about their impact on the Organic program and accreditation status of trial sites. Exploring additional design features, such as the shape and surface roughness of PIT tags, could further improve retention. Although the study did not meet the current NLIS retention requirements, the insights gained provide a promising direction for achieving higher levels of device retention in future iterations.

Challenge 3: PIT tag readability findings

In terms of PIT tag read performance, the ISC supplied Aleis Stocky stick reader was used to attempt to read all devices. However, 6 months after implantation at Esperance, only around 50% of PIT tags were able to be read using this equipment compared to 99.5% using the Fofia PT280 stick reader. Unfortunately, no panel reader was available at this site.

Given that all the tags were able to be read by at least one reader, it is possible that the source of the problem might relate to the Aleis reader. One of the disadvantages of low frequency RFID technology, is that unlike ultra-high frequency, there is an absence of anti-collision capability within the software protocol. This practically means that if two LF tags are in close proximity and are read by a reader simultaneously, then the likely outcome is that neither tag records as being read.

We explored whether the presence of two devices could have led to a “non-read” event in our case by consulting radio frequency technical experts at several RFID technology companies. Fofia confirmed that their reader is manufactured for use at a lower power level than the Aleis alternative. Furthermore, they agreed that it was possible that the Aleis reader was the source of the non-reads due to the abovementioned device read collision scenario. On the other hand, the relatively lower power Fofia reader was likely more consistently reading the implanted tag because it was the only tag it was picking up. High pressure testing (hydraulic at 5 bar for 50 hr) at ENSID technologies on recovered devices concluded that all PIT tags were functional. Finally, conversations with experts at HID confirmed that the device read collision explanation was the most likely cause of non-reads with the Aleis stick reader. Further testing on the reader devices is beyond the scope of this project.

In the case of the Jericho trial, there was no secondary RFID to create collision interference and the PIT tags also performed poorly using the Aleis reader (~90% read rate at observation 1 to ~70% at observation 2) and a Datamars TruTest XRP2 panel reader (~43% read rate at observation 2), but performed well using an alternative Datamars TruTest XRS2 stick reader (100% at observation 1). Overall, further technical investigation is required to determine the long -term performance of the transponders used in PIT tags. Reliable reads under various environmental conditions and using varied read hardware is required to satisfy the NLIS accreditation standards as specified in the HDX Tag test procedure [25].

Challenge 4: PIT tag identification

During site visits, processors emphasised the following needs:

1. The ability to reliably determine if a PIT tag is being used for identification in cattle.
2. Proof of anti-migration for the implanted PIT tag to ensure it can be easily located during removal.
3. A reliable manual backup method for animal identification in case of transponder failure, highlighting the need for visible identification codes on marker tags or other methods.
4. No additional labour required for scanning and removing implants.
5. Avoidance of the possibility of receiving animals with both external and implanted RFIDs, which could occur if a secondary RFID is mistakenly applied.

Gelita, a domestic gelatin producer, expressed a need to eliminate synthetic contaminants from ears received, as some EID and visual tags currently left on during processing can contaminate the gelatin production process. Current NLIS and State legislation require that electronic devices implanted within an animal (such as a bolus) have a separate visual marker tag. This regulation is intended to alert the supply chain to the presence of an internal device and guide specific operational actions. While boluses are not commonly used, this issue is relevant for the deployment of PIT tags as well.

Visual marker tags and earmarks

The use of a visual tag or earmark is a significant consideration. While a visual marker is deemed essential to indicate the presence of an implantable device, the challenge is to find a solution that does not negatively impact device retention rates. A visual marker itself is at risk of being lost, and while losing a visual marker does not affect traceability, it would need to be replaced, increasing costs.

Sixty percent of processors interviewed viewed a visual tag as "not a good long-term solution" and found it "counter-intuitive" to the PIT tag concept. Fifty percent supported the use of an earmark or brand as a better alternative. Among those favouring earmarks, the consensus was that a punch on the same ear as the implantable tag would be the best solution, with a triangular punch mark indicating the use of HGPs. There was broad agreement that the PIT tag should be located on the same side (off-side ear) as the current NLIS tag to minimize operational changes if PIT tags were adopted.

However, twenty percent of interviewees expressed concerns about the long-term animal welfare implications of earmarks and brands, suggesting future customer sentiment might push away from these methods. Another important issue raised was distinguishing between an RFID implant and an HGP implant in the supply chain, as both may feel similar upon ear palpation. This point requires further consultation and communication within the supply chain to ensure clear identification and resolution.

Other identification solutions

In addition to traditional visual tags and earmarks, interviewees suggested several alternative technologies and methods for livestock identification:

Tattooing: This involves imprinting a unique identifier directly onto the animal's ear or other body part using ink and a tattooing tool. Tattoos are permanent, difficult to lose or tamper with, and eliminate the need for additional external devices. However, they may be challenging to read from a distance, which can limit their practicality in some management situations.

AI Facial Recognition: This technology uses unique facial features to identify animals, eliminating the need for physical markers. It can be integrated with existing monitoring systems, reducing the need for additional tagging and potentially enhancing animal welfare. However, this approach requires investment in cameras and software, and its accuracy can be affected by environmental conditions and the quality of the visual image of the animal.

A critical aspect of using implantable RFID devices is ensuring they are clearly differentiated from HGP implants. This requires close collaboration with the supply chain and effective communication and education programs for all stakeholders on identifying and managing these devices. Currently, external ear tags are the standard for livestock identification in Australia as mandated by NLIS. While necessary for traceability and biosecurity, these tags are not ideal when used alongside internal RFID devices, as they introduce an external element to an internal solution. Addressing this issue will require policy changes to standardise the use of implantable RFID devices without redundant external markers.

Challenge 5: PIT tag removal

This project examined current methods and tools for removing EID tags and explored potential future requirements for removing implanted PIT tags, focusing on plant setup, methods, and tooling. The primary goal was to ensure the safe and efficient removal and disposal of PIT tags. Processors need any removal activity to be seamlessly integrated into existing workflows without adding new labour demands or significant capital expenditures. An assessment of available tools from livestock, metal work, and construction industries found no off-the-shelf solution, but a suitable tool could be designed and built for this purpose.

Processors generally accepted the use of manually assisted, pneumatic, or hydraulic removal tools. The designed tool must be safe, quick, and efficient, potentially featuring dual triggers for enhanced safety and integrated readers for scanning. Proper disposal of removed devices is also crucial. Waste management, including biological, plastic, and electronic components, must minimize environmental impact, and the removal process must keep pace with processing line speeds. Key insights from processor interviews include:

- Most processors follow similar procedures for RFID scanning and removal, using a wand reader post-mortem and cutting out the RFID with snips or pliers, which takes seconds.

- There was minimal concern about the equipment and process for removing an implanted device. Interviewees were confident that a simple punch tool (manual, pneumatic, or hydraulic) would suffice, aided by ear palpation.

- Processors supported the PIT tag concept if the removal process did not increase labour, time, complexity, or capital investment. The purchase of simple tools already used in the industry was not seen as an issue.

- Adoption strategies should include educational materials and demonstrations of best practices for device removal to ensure smooth integration into existing workflows.

- Variability in how processors handle cattle ears was noted. Some processors had low-value markets for ears, such as pet food, while others did not. In some cases, ears were sent to Gelita for gelatin production.

- Currently, all ears remain in domestic markets. Thirty percent of processors reported R&D projects or investments in equipment to process waste products, including ears, into higher-value marketable products. The trend towards maximizing the value of every part of the animal is expected to continue.

- Ears containing HGPs are treated differently; they are either palpated to remove the pill or downgraded to an end use unaffected by the HGP pill.

- Eighty percent of processors reported handling cattle with HGPs as part of their normal operations, unless the operation is certified HGP-free, organic, or part of a related program.

PIT tag removal tool prototype

Based on our learnings from the previous reports, desktop research, and extensive discussions with processors, a prototype tag removal tool was made shown in Figure 5. The insights gathered highlighted the need for a removal process that is safe, efficient, and easily integrated into existing workflows without additional labour or complexity. No device currently exists so we developed a design brief based on interviews with processors which can be found in appendix 7. The document called for innovative solutions to design or adapt tools that can efficiently and safely remove these tags, while also considering the possibility of leaving tags in the ear if beneficial. Key requirements for these tools include efficiency, effectiveness, reliability, serviceability, safety, and reasonable cost. The project obtained input and collaboration from industry stakeholders to produce a basic prototype, which was able to punch a circular 25mm diameter section of ear within 20-30 seconds but was insufficient to consistently perform this task with repeated samples. This speed is aligned with the current average processing line indexation time of 20-40 seconds. Options to increase the capacity of the prototypes pneumatic ram include using a larger ram, altering the cutting angle of the blade and/or receiver, adding circular motion and/or serration to the cutter. Processors did not report any specific requirement for metals or tool design to be “food safe,” but handling safety (two-handed control/dual trigger), reliability (easily replaceable blades, easy cleaning), and avoiding chain blockages were essential. Additional features of interest were a tool with an inbuilt RFID scanner and directional metal detector, useful for non-readers.

Figure 5 – PIT tag removal device prototype

5. Learnings from past experience of ag-tech adoption in Australia

The adoption of new technologies and innovations in the Australian livestock sector has historically faced significant hurdles. For the commercial use of implantable PIT tags, the challenges extend beyond the device's performance. This report has identified, through field trials and supply chain engagement, that the primary obstacles are related to PIT tag retention and read performance. Resolving these issues is crucial for advancing along the NLIS accreditation pathway. To progress, it is essential to collect comprehensive field trial data from various geographic locations, ensuring that PIT tag retention rates exceed 97.5% over an extended period and that all transponder reliability issues identified in this report are addressed. Additionally, a key operational challenge within the supply chain is developing an effective method for communicating the presence of a PIT tag in a manner that satisfies both regulatory authorities and supply chain participants.

The Global Ag-tech adoption dilemma

Animal identification and traceability is not a new concept, with the first recorded animals being identified over 3800 years ago in the Code of Hammurabi to prevent thievery [5]. In modern livestock markets, animal identification and traceability are an essential requirement and is also used for the control and monitoring of diseases and production management. Federal and state governments play a lead role in the establishment, monitoring and reporting of animal identification and traceability. Access to international markets and ensuring that the expectations of consumers concerning animal welfare, nutrition, and animal treatments (e.g. use of HGPs) are dependent upon the existence of a reliable animal identification and traceability system.

Australia is widely reported to currently have a "world-leading" animal identification and traceability system that will continue to evolve to "meet and exceed" future biosecurity needs [6]. Evidence of this evolution can be seen in the decision by federal and state agriculture ministers in late 2022 to implement a nationally consistent individual EID system for sheep and goats by 1 January 2025. It has been mandatory for all cattle nationally to be electronically tagged since 2005. Technology alternatives exist that can perform tasks within the existing animal identification system which are touted by some as being better than the current technologies. For example, the current report is investigating the potential of an implanted PIT tag as a potential alternative to the currently used external ear tag.

Research and development of these new technology options occurs to improve the offering in some way, typically to make it perform better or be more cost effective when performing a task. To assess worthiness, regulatory authorities represent a major stakeholder with the primary task of ensuring that the technology option presented satisfies national and international performance and accreditation standards. Commercial players such as cattle producers, saleyards, and processors also have their own suite of their own technology requirements that must be satisfied before committing to purchasing any new technology.

The type of organisation (i.e. start-up, small private, multi-national) endeavouring to introduce new technologies to the livestock sector will encounter some common, and some unique barriers to adoption. Common barriers to scaling a technology from an agriculture industry perspective have been previously documented by McKinsey as industry fragmentation, and a lack of standard data architectures and cross-platform interoperability [7]. Startups and other small private companies can face some additional barriers such as finding it difficult to scale due a lack of capital. Furthermore, whilst ag-tech start-ups in the recent past have reported good funding in the early stages, far fewer received later-stage funding, suggesting an inability to build the requisite customer base to secure follow-on funding [7]. The McKinsey report also highlights that although ag-tech adoption is typically slow, farmers are open to innovation, and it acknowledges the important role that regulation will play in accelerating positive industry growth through technology adoption.

Adoption Barriers for the PIT tag

The MLA report "Barriers to adoption and extraction of value from ag-tech in the Australian livestock industry" details a thorough treatment of both the theoretical and practical barriers confronting all new technologies offered to the Australian livestock market [8]. Barriers are presented under seven key themes as shown below in Fig 6.

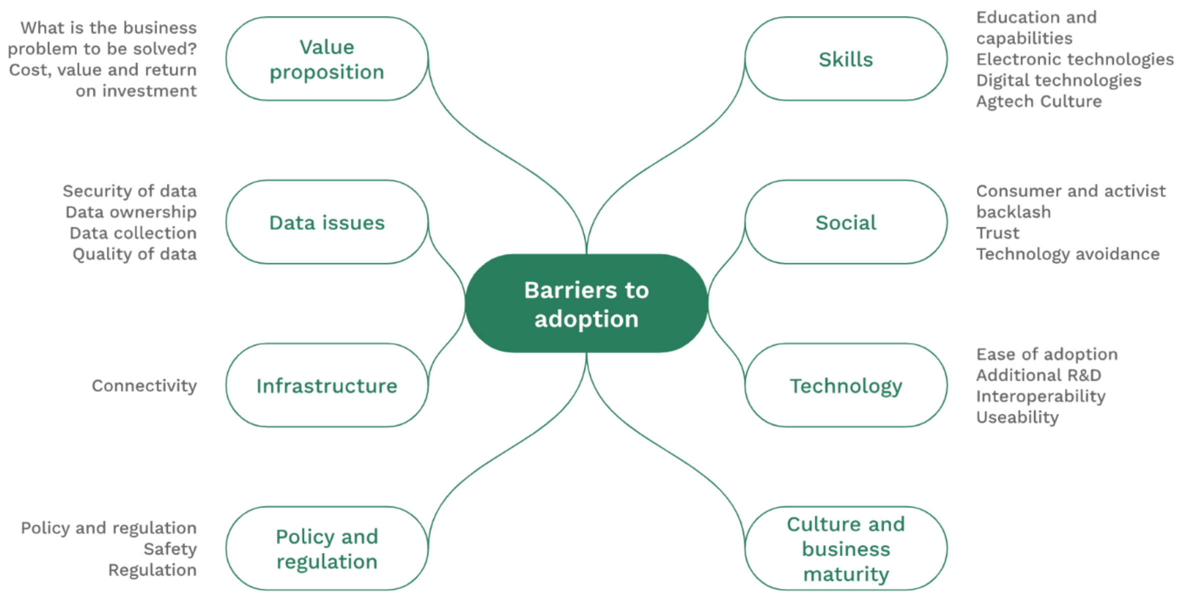

Figure 6 - Barriers to ag-tech adoption clustered according to seven themes [8]

The PIT tag concept will now be discussed from the perspective of the themes presented.

Value Proposition

A value proposition is defined as "a statement that identifies tangible and intangible benefits customers get when buying a particular product or service" [9]. It summarises how, and for whom, the benefits of the product or service will be delivered, experienced, and acquired. Customers must perceive that this product or service creates higher value than alternatives for their needs, at a reasonable cost [10]. Although a value proposition is typically developed as part of a broader marketing strategy, it is essential to help potential customers understand potential value. Typically, value propositions are only a few sentences long and are supported with statistics or facts that outline the stated value [11].

An example of a PIT tag value proposition is;
A PIT tag is an EID for life. Electronically tagging cattle protects the value of livestock for farmers and the industry. Implantable PIT tags are a permanent, cost-effective, and reliable device to meet regulatory obligations and improve cattle supply chain management.

The “jobs to be done” theory is also helpful to understand that customers "hire" products and services to get jobs done, rather than purchasing them based on their attributes and buying behaviours [12]. Accordingly, adoption of a PIT tag will require a clear and demonstrable value proposition for customers in the beef supply chain, which specifically targets the jobs to be done by these customers. Interestingly, within the beef supply chain, the value proposition is likely to vary between customer segments (e.g. regulators, producers, sale yards, processors etc) and sometimes within a customer segment (e.g, JBS, Teys, ACC etc within the processor segment) due to the differences between their jobs to be done.

An interesting anecdote that speaks to the relative importance of jobs to be done in the case of introducing EID to sheep in England. When surveying 55 sheep farmers about the introduction and practical use of external EID, respondents were asked to rate the degree of difficulty of the following jobs; applying EID devices, reading devices, transferring data to flock register, producing a movement document, dealing with lost & replacement devices, and interrogating the flock register [13]. The most difficult job identified was dealing with lost and replacement devices, which highlights the commonality in needs across geographic and sectoral borders for EID devices to be permanent.

Overall, all customer segments of Australia’s beef supply chain are fundamentally attracted to the benefits associated with the permanency of a tag for life. Other important considerations relate to the ease of use and removal, reliability and performance, regulatory compliance to meet legal and international market needs, and interoperability with current systems and practices. If all customer segments perceive that their important jobs to be done are able to be reliably delivered, and the pains of switching do not exceed the pains associated with the current external ear tag, the proposed PIT tag has the potential of industry-wide adoption.

A critical aspect of further commercial justification for this work is quantifying the impact of the current problem of an annual loss of EID tags, which results in diminished animal traceability. As a result of lost tags, previous studies have estimated that the cattle industry loses around $10 million annually due to the replacement cost of up to 3 million lost tags alone [2016-2020 NLIS database detailed in [27].

However, calculating the exact number of lost tags is complex. Factors contributing to the numbers from the NLIS database include tags that are purchased but never used, tags that are not properly retired (non-reconciled), unreadable tags, and incomplete PIC scanning. Regardless of the exact number of lost tags, EID tag loss appears anecdotally to exist based on numerous stakeholder interviews within the red meat sector. Furthermore, laboratory studies have shown that polymers used in EID tags can suffer from fatigue failure due to repetitive ear flicking behaviour common in bovines, and it is well known that certain types of fencing can be used by animals to physically pull out external EIDs [27].

Despite the difficulty in quantifying lost tags, stakeholders qualitatively recognize it as an issue. Providing indisputable numbers will help build a strong value proposition for all stakeholders and may prompt regulators to acknowledge the problem collectively. Even without proactive assistance from regulators, if tag loss is significant for large commercial stakeholders—often operating vertically integrated businesses with their own cattle, feedlots, and processing facilities—change is still possible. In such cases, the need for whole-industry data is reduced as businesses act on their data on tag loss.

Regardless of quantitative data on tag loss, presenting the performance of the implantable EID alternative to the industry is a crucial first step. Demonstrating clear improvements in EID tag retention, equal or better tag readability, and ease of application and removal is vital. However, these criteria alone are insufficient for adoption. Any new solution, including the implantable EID, must also show minimal negative consequences, such as; significant changes in operating practices, higher costs, increased risks, operational complexity, and negative impacts on domestic and international trade partners.

Further investigative work is required to determine more accurately the quantity and nature of EID tag losses post attachment. Examples of the type of data that could be collected includes the brand and model of EID design, the type of fencing used at the property, the PIC and geographic location, the condition of the animal's ear, and whether the correct application procedure was followed.

Data Issues

Security of data, data collection, quality and ownership are considerations that apply to any comparison of incumbent and future technologies. Since implantable PIT tags in this study were manufactured in low frequency (LF typically operating 125 kHz-134 kHz) RFID and were operated according to legislative requirements within Australia’s traceability system, security of data, data collection, and ownership of data considerations are the same as for external EID devices.

However, there are two potential future benefits of implanted PIT tags that originate from the device being implanted subcutaneously. Firstly, an implanted PIT tag able to demonstrate superior retention and in-field performance in animal identification and traceability would improve the quality of data and facilitate process efficiencies. That is, less physical tag loss and/or higher device read rates, could lead to improvements in the overall performance of Australia’s traceability system and likely have positive implications for export market accessibility and disease response. Secondly, an implanted PIT tag could include onboard sensors to measure biochemical and physiological processes and responses within the animal. For example, LF chips operating using the HDX protocol are currently available with a temperature sensor [14]. New capabilities, such as temperature monitoring but not limited to this, may lead to a range of additional benefits for customer segments in the beef supply chain that are particularly concerned with improving on-farm management practices and animal welfare outcomes.

New device capabilities that are developed to target stakeholder needs ("jobs to be done") would introduce new differentiating benefits beyond the primary job of animal identification and traceability, that the current external ear tag is likely incapable of achieving.

Infrastructure

Communications infrastructure, supported by internet connectivity, is an essential element in Australia's red meat traceability system. Indeed, the majority of ag-tech innovations are delivered in the digital world which are also dependent on a high degree of connectivity [15]. The existence and performance of communications infrastructure in rural areas throughout Australia has been described elsewhere [16] and the challenges in making improvements to this infrastructure remains relevant to all RFID technology options. Implanted PIT tags are detected using the same fixed panel and mobile wand read technologies that are currently ubiquitous in the beef supply chain.

Based on project learnings from field trials, communications and extension activities related to the future adoption of PIT tags would include advice about minimum standards of crushes and other restraint equipment required on-farm (e.g. head lift capability) to aid in the safe and effective PIT tag implantation. These infrastructure requirements are expected to be similar to those for any producer using HGPs. PIT tag removal at processors would require relatively inexpensive mobile pneumatic or hydraulic hole punches at a suitable location in the early stages of processing.

Policy and Regulation - Device Accreditation

Policies and regulation in agriculture can significantly affect the adoption of technologies in various ways such as by ensuring a minimum standard of performance and stimulating adoption by lowering costs through subsidies [17]. This is commonly done by both state and federal governments to demonstrate compliance with policy requirements. RFID tags of any kind used in the Australian cattle industry must first be compliant with international standards ISO 11784 and ISO 11785. Technical standard ISO 24631 provides the means of evaluating the conformance of devices by specifying the procedure for testing application and outlines the rights and obligations of the parties involved. Registered device manufacturers with a new LF (134.2 kHz) device must apply to the International Committee for Animal Registration (ICAR) as a first step. Certification involves two tests:

1) Conformance test (ISO 24631-1) against ISO 11785 with pass fail for resonance frequency of 134.2 + 3 kHz.

2) Performance test (ISO 24631-3): includes minimum activation field strength, amplitude voltage response (Vss). This test is not required for certification.

In Australia, the National Livestock Identification System (NLIS) is used for the identification and traceability of cattle, sheep and goats. NLIS reflects Australia's commitment to biosecurity and food safety and is intended to provide a competitive advantage in a global market [18]. The NLIS Standards committee plays an active role in regulating electronic animal identification transponders used in Australia to ensure "sufficient performance such that they are reliably read by existing handheld, race and high flow reader systems" [18]. The NLIS Standards require that all ISO 11784 and ISO 11785 compliant, ICAR certified tags, also pass a modified version of ISO 24631-3:2009 that includes the following additional items [19];

1) Pass/Fail tests by comparing the test device against a commercial "reference transponder" (Reference Cattle Tag: RI-INL-0243-40-P) in a range of scenarios,
2) only allowing HDX type transponders,
3) no specific organisation will act as "responsible authority", and
4) the use of a testing facility which is not formally certified as an ISO 24631-3 testing facility.

The NLIS "Pass-Fail" lab-based comparison tests against a commercial reference transponder takes some of the pass-fail criteria from international standards (e.g. ISO 11784 in relation to frequency stability) but as stated in [19] "most of the NLIS performance characteristics specified (have been) determined by comparing to transponders that are known to give an acceptable performance in the field". In this way, lab testing in Australia does not only meet the same RF requirements in accordance with ICAR certification specifications, but it creates a new benchmark.

The final stage in NLIS device accreditation involves a series of rigorous field trials, independently supervised and funded by the applicant, that statistically assess the in-field performance of the tags over time in areas including device readability and retention. In-field testing over 3 years, with conditional approval possible within 6 months, is required to be conducted as part of full NLIS device accreditation in Australia.

The Australian regulatory environment for gaining accreditation and approval to sell RFID tags in Australia appears to be a high relative bar to other international livestock markets. This serves to maintain a high standard of animal tracking system performance relative to our competitors. However, it is also possible that an undesirable effect of Australia's regulatory environment may be to reduce the competitiveness in terms of innovation and the introduction of new technologies, by limiting participation to those incumbent companies that already have a foothold in the market and/or are experienced with obtaining regulatory approval. New technology players such as start-ups, small private companies, and companies currently not currently competing in the livestock market are less likely to embark on regulatory approvals if there is a high degree of uncertainty of success.

More work can be done to simplify and streamline the regulatory process for device accreditation in Australia. Defining a standard of performance rather than linking performance to a particular device, would link technology development to the customer needs, rather than to past technology. Developing an open mindset towards the opportunities to combine animal identification devices with other technologies that monitor animal health for example, will produce added benefits to users.

Residue testing

In agriculture, the term 'residue' is generally used to describe the small amounts of agricultural and veterinary chemicals, or their breakdown products, that remain in or on an agricultural product [20]. The National Residue Survey (NRS) is a critical part of the Australian system for managing the risk of chemical residues and environmental contaminants in animal and plant products. The NRS supports

Australia's primary producers by confirming Australia's status as a producer of clean food and facilitating access to domestic and export markets.

Although this study did not include testing for residual chemicals in the trial animals, previous research on plastic PIT tags in fish provides some insights. A study involving snapper injected with 12mm or 22mm PIT tags, manufactured similarly to those used in this study (i.e., HDX transponders embedded in an epoxy matrix with an acrylic outer shell), found no evidence of bioaccumulation of silver (Ag), aluminium (Al), copper (Cu), lead (Pb), tin (Sn), or zinc (Zn) in the tagged fish [21]. This was determined by comparing liver and flesh samples between tagged fish and untagged controls. Mortality and adverse histological reactions related to the PIT tags were low, at 1-2% of the tagged populations, consistent with levels observed using other in-situ tagging methods. Additionally, physical inspection of the implantation site showed healthy connective tissue regeneration three months after implantation [21].

Interviews with Australian DAFF on-site veterinarians located at major Australian processors to carry out random testing as part of the NRS and other programs cited residue testing as a potential future requirement of PIT tag accreditation for use in cattle.

EU markets compliance

The European Union Cattle Accreditation Scheme (EUCAS) is a national animal production scheme that guarantees full traceability of all animals through the National Livestock Identification System (NLIS) [22]. The legislative basis for the EUCAS is the Export Control Act 2020 and Export Control (Meat and Meat Products) Rules 2021, which are available on the Federal Register of Legislation. EUCAS allows Australia to meet EU market requirements for beef by segregating cattle that have never been treated with HGPs. Continued access to the European Union (EU) offers a high-value market opportunity for Australian beef, despite access to the market historically being restricted due to tariffs and quotas. Presently, Australia's beef industry has access to a 7,150-tonne country specific quota (with a 20% in quota tariff) and shared access to a 45,000-tonne grain fed beef quota [23].

A key barrier to be overcome with the PIT tag concept arises due to the resemblance of an implanted tag to a HGP. This concern has been raised by several customer groups, particularly processors and DAFF on-site veterinarians. In a similar way in which, Australia can guarantee the supply of HGP-free beef into the EU market, this is also possible for PIT tags. Measures in the beef supply chain along with current legislation, would serve as the basis for best practice guides for PIT tags use would be required. These would likely include the requirement of accompanying visual markers to indicate the presence of an implant, and palpation of the injection area at processing facilities, which is currently performed at all facilities processing EUCAS beef.

Skills

The implantation procedure and tools used in HGPs is analogous to what would be required for use in PIT tags. Although some producers may initially lack the skills or experience required to implant PIT tags, those vendors using implantable PIT tags, if available, would commence a process of trial and review of available information. Approved PIT tag retailers would be required to include simple instructions to accompany user-friendly application devices. This project has confirmed that a veterinarian is not required to quickly and repeatedly implant PIT tag devices. Innovators and early adopters, according to the diffusion of innovation theory, are expected to be the first groups of customers in the cattle supply chain that would first use an approved PIT tag technology option [24].

Since the PIT tag technology does not present any additional changes in the method of data capture or processing, no additional IT or technology skills are required by the vendor. There is minimal disruption to the current process at the implantation stage of the technology. If PIT tags are physically lost or not operating correctly through the beef supply chain, the process would involve replacing the PIT with an external EID variety or reapplying a PIT.

The removal of the PIT tag at end of life would occur at the processing facility, using an inexpensive automated removal device to facilitate the rapid, repeatable and safe removal of devices. Work in this project on prototype removal tools indicates this task is imminently achievable. Suitable locations on the current processing facility setup, is best selected by the processors themselves to suit their needs. Any additional skills by human operators are not required.

Culture and business maturity

The potential adoption of PIT tags in Australia involves several cultural and industry considerations. The market introduction of PIT tags could be led by a major technology company or an established tag supplier, utilizing their expertise and resources to navigate regulatory approvals. Alternatively, a technology disruptor—such as a company with experience in other markets or a purely technological firm—might take the lead. For such disruptors, the report outlines essential steps for successful product development, including enhancing the PIT tag, developing and testing a multi-shot applicator gun, conducting field trials, and maintaining ongoing engagement with key players in the beef supply chain. This iterative process of innovation, often seen in entrepreneurial ventures, may be less familiar to traditional researchers or producers who expect a ready-to-use final product. The suitability and functionality of the PIT tag have evolved through iterative development driven by user feedback.

Despite these challenges, there is significant engagement with key stakeholders throughout the Australian red meat supply chain, which could be leveraged to further investigate and refine PIT tag solutions towards achieving functional usability and meeting performance criteria. Regardless of the type of business that may continue to drive towards the commercial adoption of PIT tags, they will require partnership with other stakeholders to educate and develop the final product.

Social

Trust in the performance of new technology typically comes from firsthand experience. For Australian producers to accept new tagging practices, they need to see and experience these alternatives on their farms or during demonstration days. Technology providers must demonstrate that the new tagging solutions meet or exceed the performance standards of current methods and offer additional benefits that existing external ear tags cannot provide.

However, some technologies struggle to gain acceptance due to consumer and activist concerns, especially when there is no long history of safe use or rigorous proof of their effectiveness. The PIT tag alternative could attract negative attention from animal welfare groups or certain members of the red meat supply chain. Some stakeholders might resist adopting new technology for reasons that are not clearly articulated or well-founded. Early studies on PIT devices, such a DEFRA funded ADAS UK Ltd study in 2012 investigated the use of injectable PITs in sheep and goats [25]. The work utilised implants measuring 22mm x 4mm and 32mm x 4mm, likely made of glass, which were administered via subcutaneous injection into the groin and ear base regions. Four separate experiments were conducted across these species, concluding that implantation in the groin region offered the best overall performance in terms of ease of application, low infection rates, and good device readability. However, a major concern was the inability to reliably recover all implanted devices, as some were not found or migrated to inaccessible parts of the animal. On 5-15% of trial animals it took longer than 90 seconds to locate the PIT tag. Such results are clearly not acceptable for a commercial device but have presented the opportunity to learn and improve. Indeed, there are zero technology options globally that have not required refinement and improvement of its physical form by method of prototyping and iterating between different versions. In this report, there are several key improvements to the device and application procedure that we have applied to cattle that has led to better results than those reported in the ADAS study above.

The introduction of PIT tags will require changes in practice, which could be disruptive and resisted by producers satisfied with their current management methods [26]. The livestock community's natural risk aversion, especially among older producers who have experienced past failures with similar technologies like glass PIT tags, is another barrier to adoption.

Technology

New technology must be simple to ensure seamless adoption into existing farming operations and on-farm data and decision support systems. The benefits of the technology must surpass the costs of implementation and the disruption to established management practices. For PIT tag technology, future research and development will focus on improving applicator guns for easier application, enhancing the technical features of the PIT tags to boost retention, and incorporating additional sensors or cross-device capabilities to enhance data collection and decision-making. Currently, the PIT tag solution offers adequate interoperability with existing technologies and a satisfactory level of usability for stakeholders.

6. Conclusion

Key findings

Field Trials

1) Plastic 22mm long PIT tags can reliably be implanted in the middle back of a bovine ear. Best results are achieved when cattle do not have previous tags or injury to the implant location. Careful adherence to the implantation procedure is essential.
2) PIT tag retention after being implanted for at least 12 months was 96.3% at the representative northern beef production operation and 76.8% at the southern beef production operation. Contributing factors to the variation in retention were operator or application procedure variance, and breed or geographical variance.
3) PIT tag readability was inconsistent with a wand reader due to some combination of transponder unreliability and variation between different readers. PIT tag readability after at least 6 months was around 91% (Aleis 7020 Stocky reader) at the representative northern beef production operation and between 99.5% and 50.9%, for Fofia PT280 and Aleis 7020 Stocky readers respectively, at the southern beef production operation.
4) PIT tag retention and migration have the potential to be adequately controlled or eliminated by the careful design of the PIT tag (materials and design), the applicator, and the application procedure. Improvements in these elements based on information contained in this report are expected to translate into higher PIT tag retention rates and better consistency between geographical sites.

Supply Chain Engagement

6) There is engineering and commercial device precedent for the rapid multi-shot application of PIT tags. This includes incorporation of a bevelled application needle, and simple application protocol.
7) An implantable PIT has the potential to be reliably removed at a processor facility by an inexpensive, effective and safe pneumatic or hydraulic powered tool. Further work is required to refine design specifications and manufacture the tool. The location of PIT tag removal will be determined by each processing facility based on specific operational needs.
8) A visual tag is essential to indicate the presence of an implanted PIT. Visual tags used in this study demonstrated 100% retention, however the combined cost of the visual tag and PIT tag must be competitive with existing ear tags to encourage adoption.
9) PIT tags may be viewed as a delivery vessel for a range of different technologies that may be useful to the Australian livestock sector to improve its performance in the areas of animal welfare and monitoring, environmental, and on-farm management performance.

Benefits to industry

Insights from this project build on the evidence base for developing and adopting implantable RFID technology across the red meat industry, particularly within processing facilities. The study highlights the importance of refining design and operational procedures to ensure seamless integration into existing systems as well as the appetite for adopting this technology among supply chain stakeholders. The adoption of PIT tags offers the potential for a "tag for life" solution, addressing the issue of tag loss while providing a platform for further innovations in animal welfare, environmental monitoring, and on-farm management.

Future research and recommendations

Additional work to accelerate the assessment of the PIT tag concept for the Australian cattle industry, and facilitate adoption planning includes;

Engagement with Potential Global Technology Providers
This project has been conducted through an informal partnership with XXXXX, a manufacturer of implantable devices. Currently, there are a small number of companies globally with the capability and expressed interest to manufacture devices for the livestock industry. Animal ID in livestock is a very large industry globally, historically dominated by companies that manufacture external tags. If the technical and operational issues identified in this report are adequately resolved, and there is a supportive regulatory framework for the accreditation of these devices, existing and new device manufacturers are likely to enter the marketplace with competitive and innovative offerings.

Support a Future NLIS Accreditation Trial for a Purpose-Built Device
There is increasing evidence that an implantable "tag for life," if validated in terms of retention and performance, would be an attractive tagging solution for certain types of producers in the Australian cattle supply chain. Research and development investment and support to technology companies are required to provide them with the confidence to invest in providing these innovative solutions, fostering an innovative and progressive attitude towards technology in Australian livestock.

Explore the Current Regulatory Framework and the Propensity for Change
This involves examining lab testing procedures and visual marker options, related to the issues identified. Further work with regulators and peak bodies is also required to understand any potential implications of PIT tag use on foreign markets and on participants in accredited programs such as organic beef.

Work Closely with the Supply Chain to Formulate Adoption Plans
Collaborate with processors and widen the involvement of food safety experts and on-site operations teams within major, vertically integrated processors. This can be achieved by formulating purpose-built trials with companies like ACC, JBS, and Teys, creating full supply chain ownership. Large, vertically integrated players can provide sufficient trial numbers, and relay operational and commercial needs real-time.

Continue to Build Long-Term Implant Data Evidence
Complete this project to provide important information for future product development. The concept of an implantable device used for animal identification also has important implications and learnings for other types of digital technology that could benefit from being implanted in cattle.

Some previous work and industry commentators suggested that implantable PIT tags were not feasible for reliable animal traceability due to concerns about retention and performance. However, based on the findings and feedback from stakeholder engagement, the authors believe that with further research and development, it is possible to create a PIT tag with retention and read performance that surpasses that of external ear EID tags.

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8. Appendix

Appendix 1 - Communications plan

Implantable RFID for cattle - Commercial Supply Chain trials
16 February 2023 - Version 1

Project details:

Project contact MLA	XX
Project delivery partner	The Growth Drivers
Budget	[TBC]

Background

The reputation of Australia as a producer of clean and safe beef products is dependent on the lifetime traceability of its cattle. Problems with tags undermine lifetime traceability (tag loss, non-reconciled post-breeder tags and tag damage). The project "V.RDA.0002 - Assessing the Feasibility of an Implantable RFID" for cattle identified that the cost of replacing lost tags in Australia is ~$10M per year, and that effective traceability systems can mitigate a significantly higher economic value risk of up to $2B in the event of a disease outbreak. Stakeholder engagement to identify key barriers to adoption of an implantable RFID were investigated, with the need to conduct field trials was found to be a priority.

The interim report results from the completed 90- and 140-day field trials in "V.RDA.0004 Implantable identification for cattle – field trials", show that various implantable RFID devices (22 and 32mm, Poly-dopamine (PDA) coated and uncoated) offer a high retention rate at the implantation site, and minimal adverse effects on animal welfare (infection). It has been recommended based on these positive results presented in project V.RDA.0004, that commercial supply chain trials are commenced immediately to collect longer-term data and test the supply chain needs.

Challenge/opportunity

The purpose of these supply chain trials is to expand on the work completed under the scientific field trials, to address the remaining adoption barriers and build on the evidence of an implantable RFID device for industry adoption. The trial procedures will closely align with NLIS RFID tag accreditation protocols and provide livestock industry technology suppliers with the confidence to invest in and commit to NLIS accreditation for implantable RFID offerings in the future.

Project objective(s)

The overarching objectives of this project is to collect the following new information and understandings:

- Application of implantable RFID device to 6-month-old cattle on commercial breeding enterprises.
- Device readability measures in different on-farm scenarios, with different brands and types of readers (I.e., stick vs. panel readers).
- Investigate and understand the supply chain operations issues, adoption barriers and tooling requirements for the implementation of implantable RFID devices including identifying potential solutions to overcome the barriers.

Comms objective(s)

- Communicate key insights and results from the supply chain trials to a board range of stakeholder, as well as other findings in prior work
- Communicate the key adoption barriers and potential solutions for key supply chain stakeholders
- Increase industry support for PIT tags

Target audience

Peak Councils | Important channel to ensure peak councils are aware of the project status and trail conclusions so that they can provide advice to their members.

1. Provide project summary brief in-person

2. Provide regular project updates.

NLIS Standards committee | The NLIS standard committee is aware of the project. They are anticipating this work will lead to the application for a device accreditation trial. The committee chair has indicated that this trial work could be used to support a commercial device accreditation trial.

Method as above.

Processors | Processors will be engaged during this project via interviews and also on-site. At Least 2 processors will be involved in executing aspects of this trial, where devices will be recovered. The results of the trial could be communicated via in person meetings, presentations at trade shows, and via industry circulars.

Producers| This is an important group who are experiencing the problem that the solution is focussed on. We intend to consult with MLA about the most appropriate methods to reach this stakeholder.

Key messages

- Objective reporting of trial purpose and results.
- Clear explanation of intended next steps.
- Connection between the Producers and technology options.

Communication of trial results according to the most appropriate language and media for the various stakeholder groups.

Audience - message, channel and tactics and implementation matrix

Audience	**Message(s)** **(Targeted messages based on your key audiences)**	**Communications tactics** **(e.g. written producer case study, video)**	**Communications channel** **(e.g. Feedback magazine, media release)**	**Responsibility (eg name and company)**	**Timing**
[list each audience type per row – eg red meat producers, livestock advisors]	*[for each audience, outline the tailored messages to be communicated]*	*[outline the proposed tactics – use a new row for each tactic]*	*[outline the proposed channels – use a new row for each channel]*	*[outline who is responsible to deliver each tactic]*	*[outline when each tactic will be delivered)*
Peak Councils	Awareness of the project status and trail conclusions so that they can provide advice to their members	*We intend to consult with MLA about the most appropriate methods to reach this stakeholder.*	*1. Provide project summary brief in-person* *2. Provide regular project updates.*	[TBC]	[TBC]
NLIS Standards Committee	The NLIS standard committee is aware of the project. They are anticipating this work will lead to the application for a device accreditation trial. The committee chair has indicated that this trial work could be used to support a commercial device accreditation trial.	*We intend to consult with MLA about the most appropriate methods to reach this stakeholder.*	*1. Provide project summary brief in-person* *2. Provide regular project updates.*	[TBC]	[TBC]
Processors	Results of the trial and benefits to industry.	*We intend to consult with MLA about the most appropriate methods to reach this stakeholder.*	*In person meetings, presentations at trade shows, and industry circulars*	[TBC]	[TBC]

Producers	Results of the trial and benefits to industry.	*We intend to consult with MLA about the most appropriate methods to reach this stakeholder.*	*In person meetings, presentations at trade shows, and industry circulars*	[TBC]	[TBC]

Outcome/KPIs

We intend to consult with MLA about the most appropriate KPIs and outcomes of the communications as the results begin to show throughout the project.

Appendix 2 - Jericho trial details

Trial location details

Form 1 - Property Details: Trial 1 Jericho QLD

Form 1 - Property Details: **Trial 1 Jericho QLD**	
Property name	X X
Property address	Tumbar Rd, Jericho Qld
Producer / manager	X X
Production System	Grass fed beef (certified organic)
Type of fencing	Plain and barbed wire, electric
Type of country	Few trees, heavy scrub, forested, open country (some)
Treatments used	Pour on drench: organic, insect sprays: organic

Device implant details

Person in charge of application: X X

Species tagged: Charbray Weaners, 5-9 months, Heifers

Implant date: 05/05/2023

Device name: XXXX 22mm uncoated (implant). Devices located with a polymeric tissue growth compound (coating) were also prepared, but excluded from use in the trial due potential conflicts with organic certification requirements.

Table 2. Form 2 - Tag application details: Trial 1 Jericho QLD

Form 2 - Tag application details: **Trial 1 Jericho QLD**	
1. Was any disinfectant or healing substance applied to animals' ears when the PIT tags were applied?	Yes - Specify: Alcohol wipes
2. Were the animals under cover from inclement weather or direct sunlight when the PIT tags were applied?	Yes - Specify: Roof, concrete
3. Did any of the tags/devices fail when the PIT tags were applied? If so, retain and send failure in the report.	No
4. How easy was it to place the PIT tag in the applicator?	easy
5. How easy was it to position the applicator (with the PIT tag) in the animal's ear?	easy

6. How easy was it to penetrate the ear with the applicator device?	easy
7. How easy was it to ensure the PIT tag was secure in the ear?	easy
8. How easy was it to remove the syringe injector after application?	easy
9. What were the weather conditions when the PIT tags were applied?	Dry, some dust, mid 20's
10. What were yard/race/crush conditions when the tags were applied?	Concrete, Dusty
11. How would you rate the product - PIT tag & applicator design, application instructions etc.?	Applicator poor - usable. Improvements required.
12. Please provide a breakdown of how many PIT tags were applied to each ear.	Left: 110 Total: 110

Appendix 3 - Jericho implantation data

Table 3. Form 3 - Implantable device application exceptions: Trial 1 Jericho QLD

Form 3 - Tag application issues: **Trial 1 Jericho QLD**		
RFID or NLIS number	**Reference ID Number**	**Note**
900 259000000566	37	Applicator pierced through ear, then re-adjusted and successfully applied (Image 1).
900 259000000600	49	"Tight" connective ear tissue led to minor laceration - application successful (Image 2).
900 259000000664	50	Applicator pierced through ear, then re-adjusted and successfully applied.
900 259000000589	63	"Tight" connective ear tissue led to minor laceration - application successful.
900 259000000624	91	"Tight" connective ear tissue led to minor laceration - application successful.
900 259000000707	108	Placement too close to head - inner 1/3.

Image 1. Cattle ID no. 37 - Applicator pierced through ear, then re-adjusted and successfully applied.

Image 2. Cattle ID no. 49 - “Tight” connective ear tissue led to minor laceration - application successful.

Appendix 4 - Esperance trial details

Form 1.2 - Property Details: Trial 2 Esperance WA

Form 1 - Property Details: **Trial 2 Esperance WA**	
Property name	Beef Machine
Property address	Condingup WA 6450
Producer / manager	X X
Company	X X X
Production System	Grass fed beef
Type of fencing	Plain and barbed wire, ting lock, electric

Type of country	Few trees/ cleared land, formally land used in a forestry project.
Treatments used	Injectables: Dectomax / Cydectin generics (as needed)

Appendix 5 - Esperance implantation data

Person in charge of application: XX
Species tagged: Angus Weaners, < 2 years old, Heifers
Implant date: 26/05/2023
Device name: XXXXX 22mm uncoated (implant). Coated devices were excluded from use due to the Jericho experience and agreed by ISC.

Table 5. Form 2 - Tag application details: Trial 2 Esperance WA

Form 2 - Tag application details: **Trial 2 Esperance WA**	
1. Was any disinfectant or healing substance applied to animals' ears when the PIT tags were applied?	Yes - Specify: Alcohol wipes - As deemed necessary by onsite vet
2. Were the animals under cover from inclement weather or direct sunlight when the PIT tags were applied?	No
3. Did any of the tags/devices fail when the PIT tags were applied? If so, retain and send failure in the report.	No
4. How easy was it to place the PIT tag in the applicator?	easy (pre loaded)
5. How easy was it to position the applicator (with the PIT tag) in the animal's ear?	Some difficulty - Head bale not adjusted. Beasts were able to move their heads vertically during implantation.
6. How easy was it to penetrate the ear with the applicator device?	easy
7. How easy was it to ensure the PIT tag was secure in the ear?	easy
8. How easy was it to remove the syringe injector after application?	easy
9. What were the weather conditions when the PIT tags were applied?	Moist and cool conditions
10. What were yard/race/crush conditions when the tags were applied?	Exposed - Earth, soft sand

11. How would you rate the product - PIT tag & applicator design, application instructions etc.?	Applicator: poor* *Comments below*
12. Please provide a breakdown of how many PIT tags were applied to each ear.	Left: 223 Total: 223

**Additional note added by person in charge of application: PIT device itself is very good - Applicator requires design iterations. Current single shot syringe needle is designed for penetration and not to 'skim' along the ear cartilage subconsciously, applicator instructions were supplied electronically and not in packaging.*

Table 6. Form 3 - Form 3 - Implantable device application issues: Trial 2 Esperance WA

Form 3 - Tag application issues: **Trial 2 Esperance WA**		
RFID or NLIS number	**Reference ID Number**	**Note**
900 259000000521	225	Excessive bleeding
900 259000000441	254	Laceration - device was double checked with the Vet that had scanner to get the read
900 259000000415	283	Laceration - resulted in minor ear damage
900 259000000449	289	2 attempts needed
900 259000000500	294	2 attempts needed
900 259000000512	300	Laceration
900 259000000501	312	2 attempts needed
-	330	Not scanned (missed scan)
900 259000000516	334	Pixie ears deformity - still applied but was difficult

Appendix 6 - Details of engagement activities

The details of individuals interviewed as part of this project are listed in Table 9 below.

It is noteworthy that several interviewees volunteered to be contacted to provide additional information or connections within their business as required. Several interviewees also volunteered to conduct trials and host site visits to support continued work on this project. The results of these activities will be reported in future milestones.

Table 9. Stakeholder engagement list

Processors	
General Manager	Teys Australia
Group Manager	ACC
Chief Operations Officer	ACC
Livestock Manager	John Dee
Livestock Manager	Kilcoy Foods
Supply Chain Manager	TFI
General Manager	Teys Australia
Manager	Borthwicks/ NH Foods
Plant Manager	Oakey Beef/ NH Foods
Senior Manager	JBS
Saleyards	
Manager	Wagga Wagga Livestock Marketing Centre
Manager	Roma Saleyards
Owner	Stock Tracks Pty Ltd
Feedlots	
Assistant Manager	Elders - Killara Feedlot
Producers	
Co-owner	Gundamain Pastoral (Producer and feedlotter)

Site Visits & Discovery Workshops

1. **ACC** - 22nd April 2024.

Implantable PIT tag concept, removal, and operational effects

2. **TEYS** -22nd April 2024.

Implantable PIT tag concept, removal, and operational effects

With additional discussions with on site Australian Government Vet.

3. **JBS** -23rd April 2024.

Implantable PIT tag concept, removal, and operational effects

4. **Gelita** - 23rd April 2024.

RFID e-waste effects

Appendix 7 - Request for solutions

THE RFID TAG FOR LIFE : Implanted plastic RFIDs in cattle

REQUEST FOR SOLUTIONS

The background

Electronic ID or Radio Frequency Identification (RFID) tags in cattle have been mandated in Australia since 1999 to enable traceability of animals in property-to-property movements. These RFID tags are physically located on individual animals and are scanned and record animal movements on a national database. This system underpins Australia's ability to locate cattle and initiate swift action in the case of biosecurity scare such as a disease outbreak. Currently, the vast majority of RFID tags are applied to the ear (akin to an earring as shown below) using a purpose-built gun.

It is well-known by industry stakeholders that RFID devices sometimes become detached from the animals ear due to various reasons, including; animal behaviours (eg catching the device on a fence which can rip the device out), device breakage/failure (eg polymer embrittlement due to UV exposure), or operator error. Animals without RFID tags cannot be identified and legally can't be transferred to another property or for further advancement in the red meat supply chain. The Growth Drivers Pty Ltd have been working with Meat and Livestock Australia and the Integrity Systems Company for several years to understand the extent of the problem and to identify and trial new and improved electronic tagging solutions.

Passive Integrated Transponders (PIT tags) are RFID tags that have identical functionality and mode of operation to the current RFID ear tags, but are designed to be implanted within the animal to reduce the potential of tag loss. Early PIT tag designs trialed in cattle were glass and were prone to migration throughout the animal away from the original implantation site. Current studies have shown that a modern plastic PIT tag implanted under the skin at the middle-back of an animal's ear offers the potential of a permanent "tag for life"[8]

Fig. 1 - NLIS ear tag

Fig. 2 and 3 - Naked PIT device and shown implanted

The challenge

The Australian beef supply chain is highly competitive with a large number and type of Processors. Some processors are part of large vertically integrated multinational corporations and others are small family businesses. All processors have designed their facility differently with consideration to the overall business objectives, finances and the available space. Cattle implanted with a PIT tag will likely require that device to be removed at its end of life, within a processing facility within Australia.

The project team is seeking further information on the following by engaging with Australian red meat processors;

1. The proportion of beef cattle that would require PIT tag removal at processing facilities. (i.e. it is possible that some processed cattle hides may benefit from an implanted PIT tag remaining in the hide if that is possible).
2. For PIT tags that require removal, to understand where a PIT tag is best removed in the various commercial processing facility settings.

8 Plastic PITs 22mm and 32mm in length, low frequency devices have been trialled under various beef supply chain conditions for periods up to 14 months. Specific physical device features, implantation technique and animal age and ear condition are recommended for optimum device performance.

3. To design or remodel a device or tool to assist in the rapid, repeatable and safe removal of a PIT tag.

Solution Requirements for PIT tag removal device or tool

Each processor will have specific requirements that suit their operation. However, the following requirements should be addressed by any potential solution;

1. **Efficiency:** Minimum removal time (maximum 20 seconds, likely less than 5 seconds).
2. **Effectiveness**: The device does what it needs to do without destroying the PIT.
3. **Reliability**: the device must be able to remove up to 2000 PITs per day without mechanical or other issues.
4. **Serviceability**: the device must be easily serviced with a ready supply of replacement parts.
5. **Safety**: The device must be designed without threat of human injury. This includes elimination of cut and crush injury as well as risk of physical fatigue or back or limb strain.
6. **Reasonable Cost**: Future iterations can involve a larger capital outlay to produce higher quality and quantities.

Potential PIT tag removal devices or tools

We are interested in manual devices, or types that require pneumatic, hydraulic or other assistance to operate. We could imagine that ear notch or DNA sampling tools might be a good place to look for existing devices or tools that could be useful.

If a device or tool already exists that you think has a high chance of success in meeting our solution requirements, that's fantastic! Please complete the **Solution Nomination Form** and we'll try it out. Include your contact details if you want to discuss this option further. We expect that there is no device or tool that can do the job perfectly off the shelf, so please include details of what you think might need modification and why in your submission. At this stage, we are primarily concerned with demonstrating a minimum viable product.

Can we leave the device in the ear?

Finally, for those folks experienced in the livestock supply chain and processing specifically, we are interested in understanding if it might be beneficial to leave an implanted PIT tag in the ear of some animals. If there are circumstances at your plant, or a plant that you are aware of, where an implanted PIT tag could remain with a hide for future identification purposes, please complete the form also.