Final report

Review of value propositions for a hyperspectral image analysis solution in red meat supply chains [Public version]

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Abstract

Multiple imaging modalities are currently utilised in the food and meat processing sector to value add and / or quality control meat products. These systems include x-ray, NIR and DEXA technologies for carcase metrics and meat composition assessment, hand-held devices for meat grading and colour analysis using RGB images, and hyperspectral solutions for foreign object detection and quality analysis.

To determine future use cases for image analysis solutions for meat processing, a desktop and customer insights analysis was undertaken using stakeholder discussion sessions. Desktop analysis included a review of the current meat safety and inspection standards as well as a review of past technology applications and competitor technology analysis. Imaging technologies, and specifically those targeted at quality analysis of offals were considered and the value proposition interrogated.

Key findings were that plant-walk throughs with key site personnel and observation of inspection processes (ante and postmortem) and offal processing were particularly valuable in identifying physical locations on the processing line and/or infrastructure where devices may be installed to add value to the plant's operation and inspection processes and may assist / provide support to meat inspectors. All stakeholders identified how technical solutions could provide support to meat inspectors and the improved utilisation and extraction of value of animal health/disease and offal product status.

In relation to inspection standards, potential amendments to CODEX to enable commencement of adoption of technical solutions was suggested through the investigation of the EU model where auxiliary inspection is utilised for pig, poultry, and bovine. It is understood that under the current standards, there is opportunity for technologies to provide pre-inspection status of conditions to the Meat Inspector, however the Meat Safety Inspector must inspect the carcase or carcase part in accordance with the standards. The location of assistive technologies prior to the Meat Safety Inspector will enable the provision of information to the Meat Safety Inspector to augment their inspection, however a value proposition for efficiency and cost effectiveness to needs to be considered.

When competitor technologies were considered, the number of technology providers operating in the Asia-Pacific is small compared to North America / Canada or Europe. This lack of co-locality suggests challenges for processor uptake / access to multiple solutions in the local market. The P&P Optica (PPO) hyperspectral system is the only system identified providing technical solutions for animal health/disease and offal product status. However, the pathway to a clear ROI remains to be established although assisted inspection remains a priority focus and an area in which increased quality assessment and reliability of feedback for producers is clearly acknowledged as an industry requirement.

In conclusion, significant opportunities exist for technologies to assist the meat inspection process, but without replacing inspectors on the line. New Objective Measurement (OM) technology to assist inspectors with more accurate disease classification and detecting sub-surface defects would provide value and increase quality assurance. Use of OM technologies gives an opportunity to increase utilisation and leverage from the On-site Veterinarians' significant training in public health and corporate knowledge to improve disease surveillance and add value, and the provision of feedback of more accurate and consistent detection of animal health/disease status would enable livestock suppliers to implement on-farm / transport practices to deliver a product with improved quality assurance and transparency.

Executive summary

Background

The purpose of the project was to evaluate the value propositions for a hyperspectral image analysis solution in red meat processing applications. This desktop exercise involved collecting and collating insights and benefits on potential applications of hyperspectral imaging in red meat industry from existing P&P Optica (PPO) system commercial installs and in-kind red meat processing partners. Insights were proposed to be gathered through a series of interviews of current commercial users of PPO imaging solution in various manufacturing applications in USA, Canada and Europe, and from site visits of in-kind beef and/or lamb processing partners. The review proposed to also consider applications of competitor's camera technology. The outcome of the project is to deliver confidential and public final reports on the insights & benefits on potential applications of hyperspectral imaging in red meat industry, including recommendations on proposed next priority R&D phases. The deliverables include an investment R&D roadmap and summary PPT findings presented to the project steering group and in-kind partner(s).

Objectives

The overall objective of the project is to evaluate the value propositions for a hyperspectral image analysis solution in red meat processing applications.

The specific objectives are:

- A desktop exercise collecting and collating insights and benefits on potential applications of hyperspectral imaging in red meat industry from existing PPO system commercial installs and in-kind red meat processing partners.
- Review of competitor technology applications.
- Collection and reporting of insights on potential red meat applications of hyperspectral imaging analysis solutions gathered through:
    - a series of interviews of current commercial users of PPO imaging solution in current commercial manufacturing applications in USA, Canada and Europe; and
    - from site visits of in-kind beef and/or lamb processing partners.
- Development of an investment R&D roadmap and summary PPT findings presented to the project steering group and in-kind partner(s).

Methodology

A phased approach was applied in the project, including:

i. **Project planning & schedule**

ii. **Discovery exercise**

An engagement framework was developed as a guide to prompt discussions with beef and lamb processors in Australia and for P&P Optica clients. A set of open-ended questions were developed to be used as the framework for discussions with key stakeholders and for framing of questions and responses.

Site visits were undertaken to gain insights and understand the potential benefits, implications and propositions of existing and potential technical solutions in relation to animal health and disease. The

use of human inspectors and how their skills were used / applied was discussed at each location. The aim of this discovery and analysis is to understand where and how support can be provided to meat inspectors and the improved utilisation and extraction of value (from technical solutions) of animal health/disease and offal product status and pricing models.

Two beef and one lamb processors were considered as likely participants in the project based on previous interest in animal health / disease detection and / or were part of the industry group for offal defect detection (MLA project P.PSH.1350), as well as participants in the Industry Calibration Working Group (ICWG). The processors invited to participate in the project were one lamb and three beef processors. An independent meat inspection provider was also invited to participate as potentially providing valuable insights of the current meat inspection process and supplier of services to industry.

iii. Review relevant Australian meat inspection standards, including AS 4696:2023

A review was undertaken of the relevant Australian meat inspection standards, including AS 4696:2023 "Hygienic production and transportation of meat and meat products for human consumption" regarding the inspection requirements for offal, carcase and beef heads. The aim was to identify the requirements and/or considerations for the use of objective measurements/devices to augment or undertake meat inspection related activities with a particular focus on compliance and operational factors. In consideration of feedback from stakeholder engagement, opportunities for the application of objective measurement technologies in ante-mortem inspection were identified and also included within the scope of this review.

iv. Review of competitor technology applications

A competitors' analysis was undertaken of existing & potential technologies that aim to support meat inspectors. The role these devices might play, and their potential efficacy in delivering meat inspection requirements was undertaken.

v. Final reports, recommendations & PPT summary.

Results/key findings

i) Discovery

1. The discovery approach involving open discussions (with a broad range of internal processor stakeholders where available) and site inspections (plant walk-throughs) proved extremely valuable in gaining insights, potential benefits and practical implications/propositions of existing and potential technical solutions in relation to animal health and disease. This was reinforced by stakeholder observations indicating that different stakeholders have different focus/value of the same data within a business.
2. The plant-walk throughs with key site personnel and observation of inspection processes (ante and postmortem) and offal processing were particularly valuable in identifying physical locations on the processing line and/or infrastructure where devices may be installed to add

value to the plant's operation and inspection processes and may assist / provide support to meat inspectors.

3. All stakeholders identified how technical solutions could provide support to meat inspectors and the improved utilisation and extraction of value of animal health/disease and offal product status.
4. A significant number of opportunities, potential projects and areas for further investigation were identified.
5. Extraction of additional value from existing technologies was a priority before adoption of new technologies.

ii) Review of Standards

1. Under the current Australian meat inspection standards (AS 4696:2023), technologies are unable to replace Meat Safety Inspectors and manual inspection procedures due to the Standards specifying that: a Meat Safety Inspector must be present during slaughter and dressing of each animal; and a number of inspection activities require manual procedures (e.g. palpation, incision and odour).
2. It is understood that under the current standards, there is opportunity for technologies to provide pre-inspection status of conditions to the Meat Inspector, however the Meat Safety Inspector must inspect the carcase or carcase part in accordance with the standards.
3. The location of assistive technologies prior to the Meat Safety Inspector will enable the provision of information to the Meat Safety Inspector to augment their inspection, however a value proposition for efficiency and cost effectiveness needs to be considered.
4. Opportunities exist (pending meeting performance criteria) for technologies to augment Meat Safety Inspectors' inspection activities.
5. The Standards state that carcase and carcase parts are not to leave the Slaughter Floor until a post-mortem disposition is applied. This requirement requires further consideration if subsequent inspection outcomes by devices with higher specificity/granularity for offals differ from the final on-floor disposition outcomes based on human inspection outcomes.
6. Requirements within the Standards were also identified requiring device design and integration considerations.
7. Potential amendments to CODEX to enable commencement of adoption of technical solutions was suggested through the investigation of the EU model where auxiliary inspection is utilised for pig, poultry, and bovine.

iii) Competitor Analysis

1. A significant number of technologies are in use throughout the international meat processing industries primarily focussing on foreign matter detection.
2. Foreign matter is identified as a key priority for the application of technology solutions above the objective assessment of quality traits due to its significant value proposition and / or impact on business recalls / market access imperatives.
3. The number of technology providers operating in the Asia-Pacific is small compared to North America / Canada or Europe. This lack of co-locality suggests challenges for processor uptake / access to multiple solutions in the local market.

4. PPO's hyperspectral system is the only system identified providing technical solutions for animal health/disease and offal product status.
5. Observations re. adoption of new technologies include:
    a. While attempting to launch hyperspectral systems, indications are that improvement in the accuracy of chemical lean measurement does not appear to be a high priority for customers, making it difficult establish an initial customer base and sites to demonstrate value in a real-world settings.
    b. While application of technical solutions for quality assessment may be successful, the progress towards commercializing a new application of technologies can fail due to:
        - Practical reasons - footprint, product traceability, environment, etc.
        - Lack of a clear business proposition - cost, ROI.
        - Lack of planning for integration / implementation.

Benefits to industry

All stakeholders identified how technical solutions could provide support to meat inspectors and the improved utilisation and extraction of value of animal health/disease and offal product status. The benefits to industry identified through this project include:

1. Significant opportunities for technologies to assist inspectors to perform roles more efficiently rather than replacement of Inspectors.
2. New Objective Measurement (OM) technology to assist inspectors with more accurate disease classification and detecting sub-surface defects.
3. Opportunity to increase utilisation and leverage from the On-site Veterinarians' significant training in public health and corporate knowledge to improve disease surveillance and add value.
4. Opportunities for processors to gain more value (e.g. supplier feedback) through more granular (accurate) inspection data.
5. The provision/feedback of more accurate and consistent detection of animal health/disease status enables livestock suppliers to implement on-farm/transport practices to deliver a better quality product.
6. Processors welcome more objective measures to support & expand their current grid payment system with producers. Specifically, additional measures of value traits including animal health disease and carcase & offal inspection.
7. Value in Animal Health data being with a single entity to enable a full history to be observed (disease patterns etc.) and a role for MLA to assist producers in data interpretation (or to direct producers to third-party providers/data aggregators for analysis and action).
8. Significant value of information that is collected/verified/accurate (as expect significant cost incurred by over-inspection).

The quantification of benefits of the objective measurement of offals is outside the scope of this project and is the focus of other MLA projects.

Future research and recommendations

A significant number of opportunities, potential projects and areas for further investigation were identified.

Potential Projects / Further Investigation

Species	Location	Comments Summary
1. All	a. Ante-mortem	i. - Investigate potential for thermal imaging to assist in identifying lameness.
		ii. - Value in matching counts of animals off trucks to records.
	b. Ante-mortem / Post-mortem	i. Thermal Sensor (Live)
		ii. Pre-warning of conditions for inspectors.
		iii. Carcase inspection
	c. Post-mortem	i. Need to test hypothesis the disposition of carcase is not going to change if post inspection also occurs in the Offal Room.
		ii. Odour detection
		iii. Pathology classification vs consolidated condition.
		iv. Potential for hyperspectral for Intramuscular Fat (IMF) & Lean Meat Yield) LMY – (Fat, yield traits)
		v. Value in undertaking a baseline (e.g. 1 week) of liver status/performance.
		vi. Voice Recognition for recording defects on an individual carcase basis.
		vii. Neurofibromas – hard to detect. Can train camera, mainly base of heart (not commonly seen, need VR for training).
		viii. Pack offal on site, investigate value proposition for carton screening. Recommend baseline as unsure of magnitude of the problem.
		ix. Identify impact / relationship of detection of individual organs and impact on full disposition
	d. Whole process	i. Baseline - Production costs for all diseases (even if sub clinical)
		ii. Do baseline (How, Cost, Business case, Payback). - Need analysis of “human” cost compared to “co-product” cost.
		iii. Need improved pathology/diagnosis (start with one organ then build up)
2. Beef	a. Ante-mortem	i. Investigate if foetus detection technology will operate on moving animal.
	b. Ante-mortem / Post-mortem	i. Identify / pre-detect carcase issues (potential for UHF Technology?)
		ii. Investigate if an elevated body temperature at point of arrival subsequently cools down.
	c. Post-mortem	i. Investigate microwave technology for density (e.g. lumpy skin).
		ii. Potential for AI models for lumpy skin (lesions may be hot depending on stage). Potential at hide puller.
3. Ovine	a. Ante-mortem	i. Sheep – confirm if thermal will work due to wool.

	ii. Automated counting of livestock on arrival. Significant value in matching counts of animals off trucks to records.
b. Post-mortem	i. CLA – aid Meat Inspectors as condition are both visible and not visible.
	ii. OM for vaccinations, pussy pockets & cheesy gland.
	iii. Re-inspection for seeds post chilling.
	iv. Soft tissue tears are a significant issue (pelt pulling). Potential to include OM/cameras to scan carcases as a 'pre-warning' of soft tissue tears.
	v. Believe over detection of nephritis. Suggest review / baseline study to understand extent of the issue.
c. Whole process	i. Develop an Animal Welfare score for a social license.

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1. Project background, purpose and scope

1.1. Background

Current offal health monitoring in abattoirs relies on visual and manual assessment by meat inspectors, a process requiring trained personnel at substantial cost to the industry. Disease conditions and contamination are required to be identified, and those incidences managed either by trimming of affected product, downgrading, or disposal, for any meat or offal products that are destined for the human food chain. This is of particular relevance for export commodities where inspection is a requirement for export status. The data generated from this manual scoring process, whilst potentially significant in specificity of disease states and incidence of defects (collectively known as 'dispositions') it is often not routinely recorded in all abattoirs, and inspection criteria can be inconsistently applied between sites and personnel, generating inconsistent data collection across the industry. Due to the cost of labour units required for this process, in some cases, routine inspection may not be financially viable in smaller operating systems or family-run businesses. Not only is labour an issue, but other issues include accuracy of subjectively identifying dispositions with consistency to avoid discounting all livestock suppliers for a day's production irrespective of whether they were compliant or non-compliant.

Whilst the current inspection process is robust, and teams that deliver this service are reliable, the current industry shortage of inspectors and the increasing requirements for product surveillance, provenance and integrity reporting create an environment where attenuated inspection may be a desirable industry option.

Charles Sturt University, P&P Optica (PPO) and a NSW beef processor has previously collaborated to investigate the potential for an image analysis solution for offal inspection, using a hyperspectral smart vision system and machine learning approach. Offal included in this analysis were specifically the beef offals of lung, liver and kidney. This preliminary project has confirmed the efficacy of this approach, with the potential for hyperspectral imaging to increase the visual acuity of this process to capture health, quality and contamination data in a single image. On this basis, it is proposed to develop a prototype offal health hyperspectral image capture system that can collect offal health data on the processing line in real-time, to partially automate offal health scoring in abattoirs and provide greater consistency, accuracy, and integrated traceability for offal products for the Australian red meat processing sector. The overall objective is to develop accurate measurement of disease conditions and overcome average pricing models and provide a consistent and reliable data collection platform for producer and processor feedback and disposition reporting.

Cattle supply chains are dependent on good animal health to ensure maximum efficiency and profitability pre- and post-processing in the abattoir. Offal tissues processed at slaughter for human or pet consumption can be impacted by downgrading or condemnation due to the presence of tissue changes related to infectious or endemic diseases or parasites. Over and above labour and yield loss issues, additional compelling propositions [personal communication with beef processor(s)] include: i) accuracy of subjectively identifying disease conditions and at times misidentification of disease dispositions, & ii) and avoiding discounting all livestock suppliers for a day's production irrespective of whether they were compliant or non-compliant. Accurate, continuous, consistent data capture would potentially allow different pricing models to be developed based on this data.

An example of the importance of providing robust and accurate disposition data can be evidenced with the example of Bovine Respiratory Disease in cattle. In lung tissue, the respiratory disease

syndrome Bovine Respiratory Disease Complex (BRD) has been identified globally as a significant disease factor in feedlot cattle, resulting in reduction in profitability at all points in the supply chain including the downgrading of saleable carcase and offal products. In the Australian setting, severe cases of clinical BRD can cost a producer up to AUD 1,700 per head by late-term mortality in the feedlot. BRD can result in condemnation of the whole carcase of the animal resulting in a severe economic risk to both the producer and meat processor. As the cost to industry is high, from both downgrade of offal and carcase from an affected animal, meat processors are paying a premium to producers whose animals are vaccinated against this disease syndrome, and/or show low rates of disease at processing. Despite improvements in disease management, BRD is still highly prevalent in feedlot systems and represents a significant management and production issue, particularly in vertically integrated operations. Subclinical BRD is difficult to diagnose in cattle grown in both feedlot and extensive (pasture) systems, and there is a limited body of literature surrounding the incidence and prevalence in both cohorts of animals. Therefore, to monitor the incidence of subclinical disease on their properties, producers rely heavily on feedback from meat processors who identify animals that have visible lesions at processing, where those same animals may not have been identified as having an active disease status on farm. The accuracy of this information is therefore paramount to ensuring appropriate mitigations can be implemented on farm or in feedlot; currently the granularity of this information provided through the inspection process is low and current / resolved disease is not differentiated, creating uncertainty in the efficacy of current disease management processes. Better, more granular data, could significantly assist the industry in combatting this key disease in production animals.

Kidney tissues are collected both for human consumption (lamb) but also are a valuable commodity for the pet food industry. Kidneys can be condemned for use in pet foods or for human consumption due to infectious disease (such as pulpy kidney or nephritis), cysts, or other nonspecific kidney disorders. In these cases, yield can be severely affected as one or both kidneys can be downgraded and/or condemned. Similarly, and perhaps more commonly, liver tissue can be significantly affected and yield lost due to presence of infectious agents such as liver fluke, hydatid cysts and / or fibrosis related to toxic exposures or liver dysfunction. As with lungs, the indication of whether an infection or infestation is current, past or chronic, is not currently provided as feedback in all disease cases, information that could potentially be of significant use to the producer. As an organ with significant yield, up to 10kg per animal in the case of beef cattle, this can result in financial loss to both the producer and processor.

Generally, producers are all collectively discounted through price averaging models to accommodate for loss of yield across the yearly cycle of production, regardless of cause. This position generates an inequity between producers managing disease well, and those for whom management or prevention may be more challenging with the former accepting the liability of the latter. This situation could be strategically alleviated where granular data at an individual carcase level are able to be collected in every abattoir across the country, regardless of size or operating partner with individual pricing models applied based on disease free, degree or diseased status. In all cases, collection of electronic offal health data for all carcases processed at abattoir, rather than just some carcases as is currently the case, can also provide important feedback to producers to assist with management of these common health conditions prior to slaughter, providing a positive incentive for practice change at feedlot and on farm.

In previous work undertaken as part of the MLA-CSU-PPO collaborative project [P.PSH.1350], PPO and CSU have developed an image analysis system capable of capture, recording and analysis of lung health scoring on the abattoir offal line. This system can identify disease in cattle lungs presented in the abattoir in real-time during abattoir processing, allowing collection of independent, quantitative data on offal health for the processor and producer. The system

operates at line speed, a necessity for large international processing companies. Current speed of operation is at a rate of one image every 25 seconds for continuous assessment, a requirement of the processing chain in order that production times are met for industry.

A prototype single-sided customised imaging system was developed that accommodated for the greater height and product variability encountered with offal. The prototype incorporated existing PPO product software, as well as developing new algorithms, that captured offal health parameters. The prototype has been designed, fabricated and commissioned to specifications required for integration into an Australian food manufacturing / processing plant and demonstration in an Australian setting, and is currently operational in the Food Pilot Plant at Charles Sturt University.

Additionally, there are several existing commercial solutions using PPO imaging analysis in many multiple manufacturing applications in USA, Canada and Europe, including detecting: leanness in pork; pale soft exudative [PSE] and dark firm and dry [DFD] conditions in pork; woody tissue in chicken breast tissue; as well as several foreign matter contamination applications in multiple food processing applications.

This desktop exercise will evaluate existing PPO hyperspectral imaging analysis solutions being currently used commercially in food manufacturing applications, as well as reviewing potential applications with site visits to in-kind beef and/or lamb processing partners, to develop a list of potential applications in red meat processing. Insights will be gathered through a series of interviews of current commercial users of PPO imaging solution in various current commercial manufacturing applications in USA, Canada and Europe, and from site visits of in-kind beef and/or lamb processing partners. Competitor(s) analysis of existing & potential technologies, and assess their efficacy in delivering meat inspection requirements. The outcome of the project will be to deliver confidential and public final reports on the insights & benefits on potential applications of hyperspectral imaging in red meat industry, including recommendations on proposed next priority R&D phases. The deliverables will include an investment R&D roadmap and summary PPT findings presented to the project steering group and in-kind partner(s).

1.2. Purpose and scope

This project seeks to evaluate the value propositions for a hyperspectral image analysis solution in red meat processing applications. This desktop exercise will involve collecting and collating insights and benefits on potential applications of hyperspectral imaging in red meat industry from existing PPO system commercial installs and in-kind red meat processing partners. Insights will be gathered through a series of interviews of current commercial users of PPO imaging solutions in various manufacturing applications in USA, Canada and Europe, and from site visits of in-kind beef and/or lamb processing partners. The review will also consider applications of competitors' camera technology. The outcome of the project will be to deliver confidential and public final reports on the insights & benefits of potential applications of hyperspectral imaging in red meat industry, including recommendations on proposed next priority R&D phases. The deliverables will include an investment R&D roadmap and summary PPT findings presented to the project steering group and in-kind partner(s).

1.3. Expected outcomes

The outcome of the project will be to deliver confidential and public final reports on the insights & benefits of potential applications of hyperspectral imaging in the red meat industry, particularly for offal disease detection, including recommendations on proposed next priority R&D phases.

2. Objectives

The overall objective of the project is to evaluate the value propositions for a hyperspectral image analysis solution in red meat processing applications, particularly disease detection in offals.

The specific objectives are:

- A desktop exercise collecting and collating insights and benefits on potential applications of hyperspectral imaging in red meat industry from existing PPO system commercial installs and in-kind red meat processing partners.
- Review of competitor technology applications.
- Collection and reporting of insights on potential red meat applications of hyperspectral imaging analysis solutions gathered through:
    - a series of interviews of current commercial users of PPO imaging solutions in current commercial manufacturing applications in USA, Canada and Europe; and
    - from site visits of in-kind beef and/or lamb processing partners.
- Development of an investment R&D roadmap and summary PPT findings presented to the project steering group and in-kind partner(s).

3. Methodology

The methodology applied to this investigation was data capture through a semi-structured interview process. Key stakeholders in the Australian processing sector were identified for discussion forums, with additional information sought from several international operators. The findings from these forums were documented and reflected in the narrative presented in this report. Additional resources were reviewed and considered in the context of the quality assurance requirements for offals and how those processes might be attenuated by the inclusion of automated assessment devices, if those devices were available. This process was considered the 'discovery exercise'. Recommendations were made based on the accumulated knowledge gained through this process.

3.1 Project planning & schedule

The following activities were undertaken as part of the project planning and scheduling activities: Formation of project steering group; kick-off meeting; trial plans; interview design; site visits schedule & timelines; and in-kind partners [minimum of 2 beef & 1 sheep]. The knowledge forum profiles and schedule were submitted to MLA for approval.

3.2 Discovery exercise

A number of site visits were conducted and discovery forum undertaken with key staff members at these processing sites. Contributors included three beef processors. International contributors were a pork processor in Canada and P&P Optica (PPO) as the industry technology partner.

In addition to the site visits, a review of the relevant Australian meat inspection standards was undertaken, including AS 4696:2023 “Hygienic production and transportation of meat and meat products for human consumption” applicable to the inspection requirements for offal, carcases and beef heads. A competitor(s) analysis of existing & potential technologies that could support meat inspection was also undertaken.

Finally, insights & benefits on potential applications of hyperspectral imaging in red meat industry from existing PPO system commercial installations in USA, Canada and Europe, and from in-kind red meat processing partners.

3.3 Final reports, recommendations & PPT summary

A final report was then compiled to deliver confidential and public-facing documents on the insights & benefits on potential applications of hyperspectral imaging in the red meat industry for both supporting meat inspection (required under AS 4696:2023) & non-meat inspection applications. This would include recommendations on proposed next priority R&D phases; the development of an investment R&D roadmap; a presentation of findings to MLA-AMPC and project steering group and sharing of key outcomes of the project with the summary with in-kind partner(s).

4. Results

4.1 Project planning

4.1.1 Project steering group

A project steering group was formed and confirmed at the project meeting on 28 November 2024, including CSU, project manager, AMPC and MLA members:

a. **Charles Sturt University (CSU):** Prof. Jane Quinn
b. **Meehan Agribusiness:** Danny Meehan
c. **Meat and Livestock Australia (MLA)**: Jack Cook; Dean Gutzke
d. **P&P Optica:** Olga Pawluczyk; Heather Galt; Tim Stork
e. **Australian Meat Processor Corporation (AMPC):** Ann McDonald (AMPC Project Manager updated and consulted, as required).

4.2 Discovery exercise

4.2.1 Stakeholder engagement, knowledge discovery process and approach

A project brief was prepared and circulated to all stakeholders during the process of engagement for project involvement and prior to processor site visits or online discussions. An engagement framework was also developed as a guide to prompt discussions with beef and lamb processors in Australia and internationally. A set of open-ended questions were developed by the project team to be used as the framework for discussions with key stakeholders and for framing of questions and responses. The

engagement framework was also distilled into the following high level discussion points for use as an informal guide during stakeholder interviews.

High level stakeholder engagement discussion points are outlined below.

1. Type of business/s.
2. Types of products produced.
3. Quality metrics currently in use (Lean, Defects & Foreign Material) & how are they assessed/measured. Discussion of current processes used, and their efficacy for data collection, for offal disease assessment.
4. Relative importance of business focus areas (e.g. brand protection; QA; customer requirements; production savings; labour savings; accuracy of performance; & risk mitigation).
5. Experience with installation, commissioning, calibration, operation, cleaning, maintenance/support & data integration of automated assessment devices.
6. Accuracy / performance, requirements and deliverables.
7. Purchasing decision process, pay-back & commercial models.
8. Experience with technologies evaluated however not implemented.
9. Value proposition/s of technology solutions.
10. Other potential applications within your business that could utilise automated processes for identification / data capture of health / disease markers or quality metrics.

The purpose of the site visits was to gain insights and understand the potential benefits, implications and propositions of existing and potential technical solutions in relation to animal health and disease. These include but were not limited to hyperspectral or standard light imaging systems, x-ray and ultrasound devices. The use of human inspectors and how their skills were used / applied was discussed at each location. The aim of this discovery and analysis was to understand where and how support can be provided to meat inspectors and the improved utilisation and extraction of value (from technical solutions) of animal health/disease and offal product status and pricing models.

The approach during knowledge forums with Australian stakeholders involved two main aspects:

1. Open discussions:
    a. Open and informal discussions with the desire to stimulate creative, innovative and free-thinking ideas regarding value propositions for technical (hyperspectral and other objective) solutions for offal and product defects in red meat supply chains.
    b. Invitations were extended to a broad range of internal processor stakeholders including those involved in the following operational areas:
        i. Leadership and senior management
        ii. Livestock management and veterinary inspection
        iii. Quality Assurance
        iv. Information Technology
        v. Meat inspection
        vi. Operations.
2. Site inspection (plant walk-through):
    a. Site walk-throughs were undertaken (where possible) from lairage through to offal packing with a “clean canvass” philosophy for potential improvements and value propositions.
    b. The walk-through of the inspection process (ante and postmortem) and offal processing was conducted with key members of the processor’s team to understand potential locations and operations where technical solutions (current and potential)

may assist. This included identifying physical locations on the processing line and/or infrastructure where devices may be installed to add value to the plant's operation.

4.2.2 In-kind partners - interviews & site visits

At the commencement of the project, two beef and one lamb processors were discussed as likely participants in the project. These processors were considered based on previous interest in animal health / disease detection and / or were part of the industry group for offal defect detection (MLA project P.PSH.1350), as well as participants in the Industry Calibration Working Group (ICWG). An engagement process was undertaken to re-affirm their formal participation in the project. The processors that were invited to participate in the project were one lamb and three beef processors. An independent meat inspection provider was also invited to participate as potentially providing valuable insights of the current meat inspection process and supplier of services to industry. Stakeholder discussions and site visits (Australia only) were conducted with the companies below (See Table 1).

Table 1. Dates, company and stakeholders involved in discussion forums from January – April 2025.

MONTH (2025)	COMPANY	STAKEHOLDER / FOCUS AREA	ROLE
JAN MAR	Processor A	Primary Processor [beef]	Corporate; R&D
JAN MAR	Meat Inspection Services A	Independent Meat Inspection Services [beef, lamb]	Corporate
JAN	Processor B	Primary Processor [beef]	Corporate; R&D
FEB	Processor C	Primary Processor [lamb]	Corporate; R&D
MAR	Processor D	Primary & Secondary Processor [beef; lamb]	Innovation; R&D; Corporate
APR	Processor E (Canada)	Primary Processor [pork]	Corporate

In consideration of feedback from stakeholder engagement, opportunities for the application of objective measurement technologies in ante-mortem inspection were identified and included within the scope of this review.

A number of common thematic areas were identified during the discussion forums and many of the discussions fell under the following thematic areas: labour impacts / benefits; OH&S impacts; business opportunities related to objective assessment; improvements / impacts to process flow; impacts on accuracy of current assessment practices; technologies as an enabler; the application of assessment technologies to current standards; opportunities for biosecurity screening / surveillance; product 'value -add' and quality assurance; opportunities for feedback mechanisms; technology as a value proposition; requirements around payback timelines; and appetite for adoption of new technologies. The impact location of these thematic areas could also be generally allocated to the following locations within the processor chain: antemortem assessment; postmortem assessment; whole of process improvement; data acquisition and feedback, and systemic / structural industry change. Key insights from each discussion forum are shown in Table 2 with potential next stage projects to address those opportunities identified in Table 3.

4.2.3 Key Insights

Table 2. Key insight summaries by thematic areas or all sites.

Thematic Area		Key Insights - SUMMARY	Species	Location
1. Labour & OH&S	a.	A need to make the role more engaging and desirable for Meat Inspectors to assist recruitment and retention.	All	System/Structural
	b.	Ante-mortem inspection for sheep is an OHS issue as inspectors need to be in pens with sheep.	Ovine	Ante-mortem
2. Opportunity	a.	More opportunities for ante-mortem Objective Measurement (OM) inspection for cattle than sheep.	Ovine	Ante-mortem
	b.	New OM technology to assist inspectors with more accurate disease classification and detecting sub-surface defects.	All	Post-mortem
	c.	Opportunity to increase utilisation and leverage from the On-site Veterinarians' significant training in public health and corporate knowledge to improve disease surveillance and add value.	All	System/Structural
	d.	Processors wish to gain more value (e.g. suppler feedback) from the significant inspection service they're paying for (>5 Inspectors on site) through more granular inspection data. However Inspectors current responsibilities are identification and recording for food safety (fit or not-fit for human consumption).	All	System/Structural
	e.	Universal feedback that there are significant opportunities for technologies to assist inspectors to perform roles more efficiently rather than replacement of Inspectors. The challenge is the value proposition from increased efficiency with associated increased cost.	All	System/Structural
3. Process flow	a.	The more information available prior to inspection, the better the outcomes. If the system indicates these are high risk, need inspector trained to respond.	All	Whole process

	b.	The earlier the detection the better - valuable to have live assessment and pre-warning of animal health issues however it will require linking/interfacing of technologies.	All	Whole process
4. Accuracy and specificity	a.	Need to manage increased specificity with increased accuracy (and establish methodology for management of increased detection rates if contamination is not visible).	All	Post-mortem
	b.	Strong need for consistency and accuracy of inspection, this will be aided by technology.	All	Whole process
5. Enablers	a.	Priority for any technology solutions to provide accurate data and it be instantly available to assist making decisions at chains speeds.	Ovine	Post-mortem
	b.	Key to link Animal Health to live animals.	All	Ante-mortem
	c.	Traceability an issue in sheep – data gaps.	Ovine	Whole process
	d.	Inspectors need systems to enable improved recording of inspection outcomes on offal trays as currently have insufficient time for recording.	Ovine	Post-mortem
6. CODEX / Inspection	a.	Need plan for amendment to CODEX to enable commencement of adoption. Investigate EU model where auxiliary inspection utilised for pig, poultry, bovine.	All	System/Structural
7. Data Management & feedback	a.	Important to provide feedback to livestock suppliers so they can implement on-farm/transport practices to deliver a better-quality product.	All	Data Management & feedback
	b.	Most companies have well established data aggregation and reporting systems however work required for standardisation of naming/reporting within and across sites.	All	Whole process
	c.	Processors welcome more objective measures to support & expand their current grid payment system with producers. Specifically, additional measures of value traits including animal health disease and carcase & offal inspection.	All	Data Management & feedback
	d.	Value in Animal Health data being with a single entity to enable a full history to be observed (disease patterns etc.) and a role for MLA to assist	All	Data Management & feedback

		producers in data interpretation (or to direct producers to third-party providers/data aggregators for analysis and action).		
8. Value proposition	a.	Any pre-warning to Inspectors needs an actionable outcome (behaviour change) to provide a value proposition.	All	Whole process
	b.	At plant level, focus on “controllable” elements (e.g. contamination) compared with "pathology" which is out of plant's control.	All	Whole process
	c.	Foreign bodies detection a major priority.	All	Post-mortem
	d.	Different stakeholders have different focus/value on the same data.	All	Whole process
	e.	Pre-screening of live animals on arrival e.g. seeds & feedback provided to producers and/or saleyards extremely valuable including potential opportunity to withhold lambs with high seed loads and return to consignment owners.	Ovine	Ante-mortem
	f.	Significant value of information that is collected/verified/accurate (as expect significant costs currently incurred due to over inspection).	All	Whole process
	g.	Recommend engaging with the specialised group of cattle Veterinarians on AVA re. value propositions and practical applications of technology solutions.	Beef	System/Structural
	h.	Considered value proposition for using OM to screen offals prior to entering the offal room for packaging.	All	Post-mortem
9. Payback	a.	Competition for capital investment within business - need to justify cost/benefit per carcase.	All	Whole process
10. Adoption	a.	Critical to see demonstration of new technology in operation at other sites.	All	Whole process
	b.	Extraction of additional value from existing technologies a priority before adoption of new technologies.	Ovine	Whole process
11. Potential Projects / Further Investigation	a.	Value in undertaking base-line studies.	All	Whole process

	b. Determine if significant value in augmentation of inspection can be achieved.	All	Whole process
12. Biosecurity	a. Value proposition for DAFF to support changes if outcomes of OM are EAD related.	All	Whole process

Table 3. Potential projects / further investigations identified for application of automated assessment of health and disease in the meat processing sector.

Species	Location		Comments Summary
1. All	a. Ante-mortem	i.	Investigate potential for thermal imaging to assist in identifying lameness / pyrexia.
		ii.	Value in matching counts of animals off trucks to eNVD records. (There is a commercial provider with beef and sheep system in operation in Australia).
	b. Ante-mortem / Post-mortem	i.	Thermal Sensor (Live)
		ii.	Pre-warning of conditions for inspectors.
		iii.	Carcase inspection
	c. Post-mortem	i.	Need to test hypothesis that the disposition of a carcase will not change if post inspection of offal also occurs in the Offal Room. (E.g. detection of a condition on offal after the carcase from which it came was inspected and considered fit for human consumption however the offal inspection could subsequently render the carcase as unfit for human consumption).
		ii.	Odour detection – disease / contamination early detection system
		iii.	Pathology classification vs consolidated condition (Acute / active, chronic, resolved)
		iv.	Potential for hyperspectral for IMF & LMY – (Fat, yield traits)
		v.	Determinations of baselines (e.g. 1 week of liver disease status/performance).
		vi.	Voice Recognition for recording defects on an individual carcase basis.
		vii.	Neurofibromas – hard to detect. Can train camera, mainly base of heart (not commonly seen, need Virtual Reality for training).
		viii.	Pack offal on site, investigate value proposition for carton screening. Recommend baseline as unsure of magnitude of the problem.
		ix.	Identify impact / relationship of detection of individual organs and impact on full disposition.
	d. Whole process	i.	Develop baseline production costs for all diseases (even if sub clinical).
		ii.	Do baseline (How, Cost, Business case, Payback) - need analysis of “human” cost to “co-product” cost.
		iii.	Need improved pathology/diagnosis (start with one organ then build up)

2. Beef	a. Ante-mortem	i.	Investigate if foetus detection technology will operate on moving animal.
	b. Ante-mortem / Post-mortem	i.	Identify / pre-detection of carcase issues (potential for UHF Technology?)
		ii.	Impact of body temperature on carcase temperature, chilling and carcase quality.
	c. Post-mortem	i.	Investigate microwave technology for density for disease detection (e.g. lumpy skin).
		ii.	Potential for Artificial Intelligence models for lumpy skin (lesions may be hot depending on stage). Potential at hide puller.
3. Ovine	a. Ante-mortem	i.	Sheep – confirm if thermal will work due to wool.
		ii.	Automated counting of livestock on arrival. Significant value in matching counts of animals off trucks to records.
	b. Post-mortem	i.	CLA – aid Meat Inspectors as condition are both visible and not visible.
		ii.	OM for vaccinations, pussy pockets & cheesy gland.
		iii.	Re-inspection for seeds post chilling.
		iv.	Soft tissue tears are a significant issue (pelt pulling). Potential to include OM/cameras to scan carcase as a 'pre-warning' of soft tissue tears.
		v.	Believe over-detection of nephritis. Suggest review / baseline study to understand extent of the issue.
	c. Whole process	i.	Develop an Animal Welfare score for a social license.

4.3 Review relevant Australian meat inspection standards, including AS 4696:2023

4.3.1 Review of Australian meat inspection standards: objectives and approach

A review was undertaken of the relevant Australian meat inspection standards, including AS 4696:2023 "Hygienic production and transportation of meat and meat products for human consumption" regarding the inspection requirements for offal, carcases and beef heads.

The approach undertaken was to identify the requirements and/or considerations for the use of objective measurements/devices to augment or undertake meat inspection related activities with a particular focus on compliance and operational factors. In consideration of feedback from stakeholder engagement, opportunities for the application of objective measurement technologies in ante-mortem inspection were identified and also included within the scope of this review.

4.3.2 Standards review key findings summary

A summary of outcomes for each Part/Section are shown in Table 4.

Table 4. Summary of Australian meat inspection standards (AS 4696:2023) with applicability to automated assessment of animal health / disease.

Part	Section	Sub-Section/s	Considerations
Part 2 Wholesomeness and operational hygiene	**4. Operational hygiene**	**4.4, 4.5**	Device Design and integration consideration
	5. Cross contamination	**5.1, 5.2**	Device Design and integration consideration
		5.10	Device Design and integration consideration
Part 3 Slaughter and dressing of animals	**6. The supply and admission of animals for slaughter**	**6.4, 6.5, 6.9, 6.10, 6.11, 6.12**	Consider work/process flow and integration and availability of device outcomes to Inspectors.
	7. Animal welfare	**7.1, 7.2, 7.3**	Device Design and integration consideration
	8. Ante-mortem inspection and disposition	**8.1**	Specific role of the Meat Inspector
		8.6 (d)	Opportunity for OM to augment, consider workflow and integration.
		8.8,	Opportunity for OM to augment, consider workflow and integration.
		8.8 (b), 8.9,	Opportunity for OM to augment, consider workflow and integration.
	9. Slaughter and dressing	**9.3**	A Meat Inspector must be present during slaughter and dressing of each animal
	Part 10. Post-mortem inspection and disposition	**10.1**	Consider aggregation of carcase parts in design and workflow.

		10.2	Records of disposition of carcase and/or carcase parts – consider in design and integration to assure correlation, audit traceability, performance monitoring and continuous improvement
		10.2 (b)	Opportunity for OM or other systems to provide assistive information.
		10.4	Carcase and Carcase parts for human consumption to be inspected (by a Meat Inspector (10.1)
		10.6, 10.7	Inspection to be carried out by a Meat inspector Presentation of carcase and carcase parts
		10.9, 10.10	Carcase and carcase parts are not to leave the Slaughter floor until a post-mortem disposition is applied.
		10.11	Opportunity for OM or other systems to provide assistive information.
		10.15	Consider aggregation of carcase parts, design and workflow.
		10.20	Records of disposition of carcase and/or carcase parts – consider in design and integration to assure correlation, audit traceability, performance monitoring and continuous improvement
Part 6 Identification, traceability, integrity and record keeping	**16. Identification, traceability and integrity.**	**16.1**	Consider traceability and integration of all data/body correlations.
Part 7 Premises, equipment and essential services	**19. Premises and equipment**	**19.1, 19.2, 19.3, 19.4, 19.5, 19.10**	Device design and integaration consideration
		19.12, 19.13	Device design and integaration consideration
	20. Hygiene and Sanitation Facilities	**20.1**	Device design and integaratin consideration
Schedule 2 – Procedures for post-mortem inspection	**Table 1 – Procedure for post-mortem inspection of carcases**		Note requirement for palpation and Incision.
	Table 2 – Procedure for post-mortem inspection of viscera		Note requirement for palpation and Incision
	Table 3 – Procedure for post-mortem inspection of heads		Note requirement for Incision
	Table 4 – Additional post-mortem inspection procedures when gross abnormalities and specific diseases are detected or suspected.		Note requirement for palpation and Incision
Schedule 3 – Ante-mortem and post-mortem dispositions	**Diseases and other abnormalities:**		Notes that carcase or carcase parts unfit for human consumption may be recovered or animal food subject to heat sterilisation.
	General findings:		– Odour specified as a criteria for observation. Fever noted as a criteria for observation. Opportunity for assistive technology.

Key findings of this review identified the following areas of importance in the consideration of inclusion of automated / objective assessment devices.

1. The Standards specify that:
    a. A Meat Safety Inspector must be present during slaughter and dressing of each animal; and
    b. A number of inspection activities require manual procedures (e.g. palpation, incision and odour).

    These conditions preclude current technologies replacing the Meat Safety Inspectors and manual inspection procedures under the current standards however augmentation of their process is applicable.
2. It is understood that under the current standards, there is opportunity for technologies to provide pre-inspection status of conditions to the Meat Inspector, however the Meat Safety Inspector must inspect the carcase or carcase part in accordance with the standards and be the determinant of, and confirm application of a particular disposition.
3. The location of assistive technologies prior to the Meat Safety Inspector will enable the provision of information to the Meat Safety Inspector to augment their inspection, however a value proposition for efficiency and cost effectiveness to needs to be considered.
4. Opportunities exist (pending meeting performance criteria) for technologies to augment Meat Safety Inspectors' inspection activities.
5. The Standards state that Carcase and Carcase Parts are not to leave the Slaughter Floor until a post-mortem disposition is applied (including PASS as a criteria). This requirement requires further consideration if subsequent inspection outcomes for offals differ from the final on-floor disposition outcomes based on devices with higher specificity/granularity.
6. In relation to carcase or carcase parts, those unfit for human consumption may be recovered for animal food subject to heat sterilisation. The potential for increased specificity of assessment devices raises consideration for the levels of severity being applied as a criteria for selection of carcase parts and their potential use cases.
7. Requirements within the Standards were also identified:
    a. Requiring device design and integration considerations. This refers to requirements including: physical location and operation; operational space; cross-contamination management; and data recording, integration and display (for actional outcomes by Meat Inspectors or other relevant staff and operations e.g. sorting).
    b. Where work/process flow and integration and availability of device outcomes to Inspectors could be considered as an augmentation of the inspection process.
    c. Consideration in relation to traceability and integration of all data/body correlations (animal EID to hook to offal tracking).

4.4 Review of competitor technology applications

A competitors' analysis was undertaken of existing & potential technologies that aim to support meat inspectors including vision systems (RGB, multispectral, hyperspectral) and x-ray systems. The role these devices might play, and their potential efficacy in delivering meat inspection requirements was undertaken.

4.4.1 Review of competitive technologies

An initial review and competitors' analysis of existing & potential technologies that aim to support meat inspectors is shown in Table 5. The table below indicates the region and country in which the

head-office or primary base is located and the primary types of imaging used by each company identified in the competitor analysis

A total of 58 companies were identified with the majority having head office/base located in North America (36, 62%), followed by Europe (19, 33%) and only 3 (5%) companies with a primary location in the Asia-Pacific region (Table 5).

Table 5. Technology competitor analysis and imaging types by region (current as of March 2024).

Region (HQ/Base)	Country (HQ/Base)	Types of imaging	Company
1. Asia	a). China	i). Vision, X-ray & metal detectors	- Techik
	b). Japan	i). High resolution X-ray line scan cameras	- Hamamatsu
		ii). X-ray and metal detectors	- Anritsu
2. Europe	a). Austria	i). Hyperspectral (Chemical Imaging Technology)	- InSort
	b). Denmark	i). Vision (shape, size, colour)	- JLI Vision
		ii). X-ray	- FOSS MeatMaster
	c). Norway	i). Hyperspectral	- HySpex by Neo - Maritech
		ii). Multispectral & Hyperspectral sorting	- TOMRA
	d). Spain	i). X-ray with multi-spectral capability	- Deep Detection
	e). United Kingdom	i). Camera / vision with AI software	- Motion Ai (Automation Intelligence)
		ii). X-ray	- Sapphire Inspection systems
		iii). X-ray and metal detectors	- LOMA Systems
	f). Iceland	i). X-ray, Spectra (Multi-spec), 2D/3D Camera	- Marel
	g). Switzerland	i). X-ray + Vision	- Mettler Toledo
	h). Italy	i). Vision (in-package inspection)	- ViewTech
		ii). N/A	- PlantView
	i). Germany	i). Machine Vision	- Basler
		ii). Metal detectors, magnets, X-ray (for end of line)	- Sesotec
		iii). Vision, X-ray & metal detectors	- Bizerba USA
		iv). X-ray + Vision	- WIPOTEC
		i). Hyperspectral & Machine Vision	- Frontmatec
3. North America	a). USA	i). 2D & 3D imaging	- Cognex - Landing AI - MARBLE Technologies - Radiant Vision Systems
		ii). Analytics with AI with software solutions	- Power BI (Microsoft)
		iii). Hyperspec - Nut application only / Vision system for meat	- Key Technology
		iii). Hyperspectral	- HinaLea Imaging - Impact Vision - Headwall Photonics

	iv). Machine Vision	- SMART VISION WORKS (KPM)
	v). Metal Detection	- Eriez Xtreme Metal Detectors
	vi). Multi-Eye Hyperspectral and 2D (shape) / 3D (height)	- Eye Pro Systems (KPM Brand)
	vii). Spectroscopy (FT-NIR)	- Bruker
	viii). Vision - shape, size, colour	- Neurala
	ix). Vision (digital watermarks)	- Evrythng
	x). Vision, X-ray & metal detectors	- TDI PackSys
	xi). X-ray	- ISHIDA - JBT
	xii). X-Ray & CT	- FlexXray
	xiii). X-ray / HD Camera	- ProSpection Solutions
	xiv). X-ray + AI (X-ray as a service)	- Greyscale AI
	xv). X-ray and metal detectors	- A&D Inspection - Rapiscan
	xvi). N/A (packaging solutions)	- SealedAir
	xvii). N/A (Traceability, food safety compliance & supply chain transparency)	- Trustwell (formerly FoodLogiQ)
	xviii). N/A	- Hygeiena (Sure Trend) - Ignition
b). Canada	i). 2D/3D camera + Mulit-spec in P Series	- Sightline (KPM Brand)
	ii). Colour camera	- UBI Meat Experts
	iii). Hyperspectral	- P&P Optica - MatrixSpec Solutions
	iv). Machine Vision	- Keyence
	v). Metal Detection	- Fortress Technology
	vi). X-ray	- ABM Equipment - Xray Reclaim
	vii). X-ray + Vision	- Lizotte Machine Vision

Providers utilise a vast range of technologies, including x-ray and hyperspectral imaging, to provide commercial solutions to detect foreign matter/objects and adulteration in products produced across the meat industries. However, only two providers (Rapiscan and PPO) were identified as being involved in the detection of offal diseases/defects for the purposes of offal inspection. [Refer to Section 4.4.1.1 and 4.4.1.2.

Businesses were reviewed in relation to the following categories / criteria (Table 6).

Table 6. Business review categories for companies with imaging systems applicable to animal health / disease detection in the meat processing sector.

1	A. Company Name	24	Key investors (if available)
2	Artificial intelligence (AI)	25	Lighthouse Clients
3	Australian Presence - Type	26	Location
4	Australian Presence / Collaboration	27	Market Segments
5	Case Studies/ROI demonstrated	28	Marketing / Competitive taglines
6	Company Essentials	29	Marketing Strategy
7	Company Size / Inspection Product Offerings	30	No. of Employees
8	Complete Hyperspectral-driven Food Analytics system	31	Offal Defect Detection / Grading
9	Cost	32	Offal Defects (SUMMARY)
10	Customization of Product	33	Operates in Meat/Food space
11	Detect Metal (type)	34	Other markets/products
12	Detect Plastics	35	Positioning
13	Detect Wood/Cardboard	36	PR and Outreach
14	Events	37	Product Offering
15	Existing Customers	38	Region (HQ/Base)
16	Fat/lean	39	Reported Profitable
17	Funding $	40	Reported Revenue
18	Grading:	41	Service and Support
19	Hyperspectral Grading	42	Shape, colour, size only
20	Hyperspectral-driven Food Analytics system	43	Type of imaging used
21	Inline Sorting	44	Variety of products offered
22	Inline System	45	Videos
23	Inspection Rates	46	Yearly Maintenance

4.4.1.1 Rapiscan

A collaborative project (Gutzke et al., 2023) between MLA, Rapiscan Systems and The University of Sydney developed a pre-commercial multi-sensor platform and algorithms. This platform combined multi-energy X-ray (MEXA) with visible (VIS) and shortwave infra-red (SWIR) hyperspectral camera data and associated algorithms to automatically detect and sort cattle and sheep organs with defects in abattoirs.

The proposed multi-sensor approach utilises X-ray penetrate tissues providing information inside the organs whereas the hyperspectral data provides detailed information on the surface of the organs. The focus was on the detection of defects in beef liver, lungs and kidneys with health issues (hydatids, abscesses and fluke).

The system was able to detect organs with defects with an average accuracy of greater than 90% in specific beef offals with the platform appearing to show promise for the automatic detection of defects in organs. Results from beef offal disease detection concluded that multi-energy X-ray technology can be used to aid inspectors in the abattoir and infer the presence of potential lesions and their location within organs. However, the data collected at the preliminary phase was not useful

for algorithm development required automate the detection. Further refinement to the intensity of the X-ray bands and the distance between them may be required.

In contrast to X-ray data, the hyperspectral data from both VIS and SWIR regions showed a great potential for automated anomaly detection of both beef and sheep organs and seems a more feasible solution in the short term if full automation is sought. Automatic identification of defects in both beef and sheep organs using hyperspectral imaging showed up to 92% accuracy. The algorithms developed can work automatically either 'flagging' organs with defects after classification or showing an image with coloured regions where the anomaly is detected, which could assist inspectors for further inspection.

4.4.1.2 P&P Optica (PPO) hyperspectral 'Smart Imaging' technology and market observations

i) Foreign Material Detection

The primary market segment that PPO operates in is foreign material (FM) detection (non-meat products such as metal, wood, plastic) in meat processing and post-processing lines. They currently have systems deployed in pork, chicken and other mixed commodity processing plants in North America, Canada and Europe. PPO has nearly two decades of experience in delivering hyperspectral solutions for FM detection for the meat processing sector, with each system installed being specific to the commodity type (bovine, porcine, avian), meat product (whole tissue e.g. chicken breast, chunks or cuts) and object to be detected (metal, plastics, paper, cardboard, wood). Each solution is developed with the processor to meet the specific needs of the product, contaminant and reporting requirements.

PPO has observed that the North American meat industry has generally been receptive to new technologies to address FM contamination in specific cases when contaminations are creating an immediate market access issue. These market access crises can be, for example, the risk of losing a major customer or export market area, or in reaction to a major recall or other negative food safety issue.

For companies that were in a business-critical situation, deciding to invest in foreign material detection technology could be a long, drawn-out process. These projects compete with other more urgent expenditure (e.g. building repairs, replacing broken equipment, etc.) where reaction to an immediate issue predicated a faster decision-making process. The non-crisis driven early adopters of PPO technology were generally large innovative companies that had strong mandates around food safety. These companies had already decided that they would invest in assessment tools to reduce their foreign material risks and had set aside a budget for these projects as an investment strategy in quality assurance.

In support of PPO's approach to the marketing of their systems, PPO have significant high quality and in-depth resources available to customers and potential customers on their website (https://ppo.ca/) including: blogs; videos; case studies and briefs; and brochures. PPO also markets through channels including LinkedIn where a Return On Investment (ROI) calculator (Excel spreadsheet) for automated inspection systems is available to potential customers to assess the value proposition for the adoption of PPO's FM detection systems. PPO highlights in a LinkedIn post that

> "… In today's meat processing industry—where labour shortages, product safety and quality pressures collide—making data-driven bets on new tech isn't optional—it's essential.

"PPO breaks down how to calculate the real ROI of automated inspection systems, highlighting four measurable areas:

1. Optimize labour and boost skills: Automation can save \$50K–\$75K/year per inspector—and creates space to train staff in higher-value roles.
2. Slash condemned product: Some plants see up to an 80% reduction—and savings of \$500K–\$1M annually—by minimizing waste.
3. Cut chargebacks by 40%: Utilizing PPO Insights enabled one facility to identify upstream issues before they became customer problems.
4. Avoid costly recalls: Recalls cost food companies nearly \$10M—and foreign material is the top culprit. PPO helps protect your brand and bottom line—with verifiable data.

"Key takeaway: Done right, inspection systems aren't a cost centre—they're a strategic investment. PPO offers a user-friendly ROI calculator to help teams model these benefits for their own operations.

"Ready to validate potential ROI with data? Read more and download our ROI Calculator: https://ow.ly/hUSE50WJyJq"

The LinkedIn post and ROI Calculator are contained in the appendix (See Section 7.3). The areas identified for consideration for quantification in relation to FM detection include:

1. Resources removed from inspection;
2. Resource reallocation;
3. Product wasted annually (dispose, charge back, etc.);
4. Downtime associated with FM findings (organics); and
5. Recall (total calculated cost)

The quantification of the value proposition for the automated and objective assessment of offals is currently considered more complex than automated inspection of FM due several reasons including:

- Current meat inspection Standards specify that a Meat Safety Inspector must be present during slaughter and dressing of each animal; and several inspection activities require manual procedures (e.g. palpation, incision and odour). These conditions preclude current technologies replacing the Meat Safety Inspectors and manual inspection procedures under the current standards, however augmentation of their process is applicable (refer 4.3 Review relevant Australian meat inspection standards, including AS 4696:2023)
- The purpose of existing inspection systems in Australia is focused on the assessment of the disposition of offals as being fit (or not) for human consumption and were not developed with the objectives for assessing the quality of offals on a more granular basis.

Some of these issues are referenced in sections 4.3 Review relevant Australian meat inspection standards, including AS 4696:2023).

In addition, the quantification of benefits of the objective measurement of offals is outside the scope of this project and is the focus of other MLA projects.

In PPO's experience, a risk-averse mentality generally applies to new technology investments in the North American market as most companies don't want to take the risk of being the first to adopt a new technology, or uptake newer technological solutions for existing issues. In general, PPO's observations are that the Australian meat industry are early adopters of innovation than North America, with Europe showing specific regional differences in adoption comparative to the other regions.

ii) Examples of Quality Assessment Applications

PPO has experience with developing a small number of different quality related applications of their hyperspectral vision systems over the years. Two specific examples are in woody breast detection in chicken and pork loin quality assessment.

a) Pork Loin Grading

The goal of this application was to develop a system to identify and sort pork loins meeting the "Japan-grade" criteria for export quality (loins with the best colour and texture were sent to this export market). In this case, the current standard was human graders that would inspect each loin to designate whether it met the Japan quality criteria, similar to the Australian MSA IMF grading system, and was similarly reliant on the human as the assessor. Availability and consistency of trained assessors was therefore a limiting factor for this processor, hence seeking an automated solution. A *de-novo* PPO hyperspectral algorithm was developed by collecting a library of images with corresponding grades and other objective measurements (colour, pH, quality defects, etc.). Expectedly, an early finding was the variability in human graders with different graders producing wildly different scores and poor repeatability of their subjective assessment criteria. PPO found it was critical to fall back on the objective data to attempt to train the system with a level of accuracy. PPO was ultimately able to demonstrate a reasonably strong correlation between hyperspectral data and subjective "Japan grade" prediction based on the data set collected and objective assessment measures applied. The project did not proceed to permanently implementing a solution due to plant space limitations and difficulties with product traceability in the boning and cutting room. Both issues are common impediments to using technology for meat grading and identified the need for integrated solutions as part of any new technology process.

b) Woody Breast - Chicken

Woody breast is a meat quality issue caused by abnormal growth and development of the pectoral muscles (breast) in broiler chicken. In these cases, the breast material contains higher levels of collagen than in unaffected chicken breast making the breast meat 'woody' (stiff in nature) and of poor cooking and eating quality. Breast meat can be either mildly, moderately or severely affected, with corresponding impacts on eating quality. The goal of this project was therefore to sort all breasts by woody breast severity with those affected being selected into a reject stream rather than directed for human consumption. At the outset of the project, this customer was performing some woody breast "spot-checking" to provide feedback to the farms and improve overall quality, but this process was laborious and required a dedicated labour unit to be present on the processing line for every shift. Given the speed and volume of materials to be analysed, this proved to be inefficient and inconsistent, with the quality of feedback therefore impacted by that process. An automated assessment approach was therefore required to overcome this issue.

PPO trained its system based on a data library captured in the production plant. Samples of all woody breast severities were collected (mild to severe), scanned, and independently graded by

three trained industry graders in the plant. The intention for use of triple-grading each sample was to remove outliers and assure data quality for training and testing the models.

Unfortunately, the three graders' results proved highly inconsistent, illustrating the variation in human grading as an objective assessment tool. Following iterations of model development, a solution was developed that resulted in >90% accuracy at identifying severely affected breast meat, an outcome that exceeded the customer's previously stated targets and was better than the human graders in terms of consistency. The system was able to predict and sort chicken breast by "woody-ness" into good, mild, and severe categories.

iii) Chemical Lean Analysis

Most facilities in North America and Europe use some form of technology as part of their chemical lean measurement and control process, the majority using X-ray (bone content) or NIR (e.g. fat / lean) technologies for composition analysis. PPO has investigated opportunities to incorporate Lean Meat Yield (LMY) analysis into their hyperspectral toolkit as hyperspectral analysis can be highly sensitive to composition analysis, such as for comparison of fat and meat yield, where those constituents have significantly different spectral fingerprints.

a) Off-line measurement

The customer uses a method for selecting a small sample that is "representative" of a larger batch. This sample is then homogenized and measured via benchtop equipment (i.e. Foss NIR fat analyser). The drawbacks of this method are the time delay between sampling and results (at least 15mins - this lag in the data can have impacts on production) and the method used for selecting a small sample from an entire batch (this is a huge source of error - often they are trying to "randomly select" 1kg of meat from a batch that is 1000's of kgs).

b) In-line measurement of composition

One of the most common in-line technologies used in the processing industry is for the assessment of lean meat yield (LMY). The most common in-line technology used today is dual-energy x-ray (i.e. Foss Meatmaster). This technology estimates the lean and fat composition based on the density of the product. Customers report that although this is an accepted standard, they know that it has limited accuracy. There can also be inconsistencies based on how the x-ray images are analysed. There are assumptions regarding the overall moisture/protein content that are based on average data of different species, muscle groups, etc.

PPO have developed algorithms that can accurately assess composition of meat products (muscle / fat / bone) to determine LMY in pork products at line speed. PPO have observed in general that while attempting to launch hyperspectral systems into this market, the improvement in the accuracy of chemical lean measurement does not appear to be a top priority for customers. PPO have also observed that other potential competitors in this space have also focused more on Foreign Material (FM) detection. Again, this could potentially relate back to urgency/priorities where improving the accuracy of chemical lean is considered a "nice-to-have" or has an uncertain price-point implication, while FM problems can cause a crisis requiring immediate investment due to substantial financial losses in the cases of contamination or quality assurance breaches.

Overall, the PPO experience of the development of novel imaging solutions for the meat processing sector is that uptake of technologies is largely driven by food safety or quality assurance imperatives where business-critical impacts could be averted or avoided by utilisation of a technology solution. Consistency was valued as a business proposition, as was the re-utilisation or attenuation of labour units within the plant. It is likely that similar considerations will be apparent in the uptake of any disease detection systems in Australia.

4.5 Value Proposition

The project will deliver the following information on the value proposition and potential benefits to the Australian red meat industry for:

4.5.1 Cost to industry and size of the market

Condemnation of disease-impacted offals costs the beef processing sector approximately $50 million/yr. From a producer perspective, previous research has shown that health conditions can affect carcase weight and daily gains, and liver fluke can be used as one example. For one abattoir, due to liver fluke alone, there was a loss of $449,308 due to reduced carcase weight over a three-month period, a loss that can be extrapolated out to an annual figure of $1,797,235.

The current costs of animal health monitoring to the Australian red meat processing sector have been estimated to be $135M per annum. Whilst already impressive, this figure does not account for losses from incorrect identification of disease and unnecessary condemnation of meat products and is therefore likely to be a significant underestimate the industry impact. Equally it does not consider the quality assurance value of an independently verified and quality assured system to add value to our export markets.

Development of these automated diseased tissue detection solutions could significantly reduce the labour costs associated with animal health recording while increasing the accuracy of produced data. There are currently estimated to be around 150 processing operations in Australia for which this technology may be applicable, with this number growing exponentially for an international market. The prototype under development, therefore, represents a system that could be extended to all types of offal and other species over time, increasing market share and profitability by providing continuous, automated data capture on all aspects of the carcase for verification and quality assurance processes.

4.5.2 Adding value to Australian meat products for a global export market

Export markets may be highly volatile for abattoirs and measures that increase the assurance of quality will help retain market share through maintaining consumer satisfaction. Employing automated detection systems in the abattoir production line can reduce the handling of offals, leading to decreased cross-contamination and increased food safety outcomes. The data produced may also be incorporated into provenance information, a feature that has been seen to be increasing demand from consumers who seek guaranteed ethically sourced, welfare-friendly and high-quality animal products.

If successful, the invention will reduce variability, increase granularity of recorded data, and reduce costs associated with disease surveillance (currently $135M p.a.). Development of a minimum viable product will allow pursuit of both patent protection and industry investment for future development of integrated hand-held products and / or fixed systems.

This report will consider current appetite for adoption of offal disease detection technologies, industry readiness, and potential in-line positioning for devices and integration into existing quality assurance practices.

5. Conclusion

5.1 Key findings

5.1.1 Discovery

1. The discovery approach involving open discussions (with a broad range of internal processor stakeholders where available) and site inspections (plant walk-throughs) proved extremely valuable in gaining insights, potential benefits and practical implications/propositions of existing and potential technical solutions in relation to animal health and disease. This was reinforced by stakeholder observations indicating that different stakeholders have different focus/value of the same data within a business.
2. The plant-walk throughs with key site personnel and observation of inspection processes (ante and post-mortem) and offal processing were particularly valuable in identifying physical locations on the processing line and/or infrastructure where devices may be installed to add value to the plant's operation and inspection processes and may assist / provide support to meat inspectors.
3. All stakeholders identified how technical solutions could provide support to meat inspectors and the improved utilisation and extraction of value of animal health/disease and offal product status.
4. A significant number of opportunities, potential projects and areas for further investigation were identified.
5. Extraction of additional value from existing technologies was a priority before adoption of new technologies.

5.1.2 Review of Standards

1. Under the current Australian meat inspection standards (AS 4696:2023), technologies are unable to replace Meat Safety Inspectors and manual inspection procedures due to the Standards specifying that: a Meat Safety Inspector must be present during slaughter and dressing of each animal; and a number of inspection activities require manual procedures (e.g. palpation, incision and odour).
2. It is understood that under the current standards, there is opportunity for technologies to provide pre-inspection status of conditions to the Meat Inspector, however the Meat Safety Inspector must inspect the carcase or carcase part in accordance with the standards.
3. The location of assistive technologies prior to the Meat Safety Inspector will enable the provision of information to the Meat Safety Inspector to augment their inspection, however a value proposition for efficiency and cost effectiveness needs to be considered.

4. Opportunities exist (pending meeting performance criteria) for technologies to augment Meat Safety Inspectors' inspection activities.
5. The Standards state that Carcase and Carcase Parts are not to leave the Slaughter Floor until a post-mortem disposition is applied. This requirement requires further consideration if subsequent inspection outcomes by devices with higher specificity/granularity for offals differ from the final on-floor disposition outcomes based on human inspection outcomes.
6. Requirements within the Standards were also identified requiring device design and integration considerations.
7. Potential amendments to CODEX to enable commencement of adoption of technical solutions was suggested through the investigation of the EU model where auxiliary inspection is utilised for pig, poultry, and bovine.

5.2.3 Competitor Analysis

1. A significant number of technologies are in use throughout the international meat processing industries primarily focussing on foreign matter detection.
2. Foreign matter is identified as a key priority for the application of technology solutions above the objective assessment of quality traits due to its significant value proposition and / or impact on business recalls / market access imperatives.
3. The number of technology providers operating in the Asia-Pacific is small compared to North America / Canada or Europe. This lack of co-locality suggests challenges for processor uptake / access to multiple solutions in the local market.
4. PPO's hyperspectral system is the only system identified providing technical solutions for animal health/disease and offal product status.
5. Observations re. adoption of new technologies include:
    a. While attempting to launch hyperspectral systems, indications are that improvement in the accuracy of chemical lean measurement does not appear to a high priority for customers making it difficult establish an initial customer base and sites to demonstrate value in a real-world settings.
    b. While application of technical solutions for quality assessment may be successful, the progress towards commercializing a new application of technologies can fail due to:

- Practical reasons - footprint, product traceability, environment, etc.
- Lack of a clear business proposition - cost, ROI.
- Lack of planning for integration / implementation.

5.2 Benefits to industry

All stakeholders identified how support technical solutions could provide support to meat inspectors and the improved utilisation and extraction of value of animal health/disease and offal product status. The benefits to industry identified through this project include:

1. Significant opportunities for technologies to assist inspectors to perform roles more efficiently rather than replacement of Inspectors.
2. New Objective Measurement (OM) technology to assist inspectors with more accurate disease classification and detecting sub-surface defects.

3. Opportunity to increase utilisation and leverage from the On-site Veterinarians' significant training in public health and corporate knowledge to improve disease surveillance and add value.
4. Opportunities for processors to gain more value (e.g. supplier feedback) through more granular (accurate) inspection data.
5. The provision of feedback of more accurate and consistent detection of animal health/disease status enables livestock suppliers to implement on-farm/transport practices to deliver a better-quality product.
6. Processors welcome more objective measures to support & expand their current grid payment grid system with producers. Specifically, additional measures of value traits including animal health disease and carcase & offal inspection.
7. Value in Animal Health data being with a single entity to enable a full history to be observed (disease patterns etc.) and a role for MLA to assist producers in data interpretation (or to direct producers to third-party providers/data aggregators for analysis and action).
8. Significant value of information that is collected/verified/accurate (as expect significant cost incurred by over inspection).

The quantification of benefits of the objective measurement of offals is outside the scope of this project and is the focus of other MLA projects.

4. Future research and recommendations

A significant number of opportunities, potential projects and areas for further investigation were identified.

Table 7. Potential Projects / Further Investigation

Species	Location	Comments Summary
1. All	a. Ante-mortem	i. Investigate potential for thermal imaging to assist in identifying fever / inflammation.
		ii. Value in matching counts of animals off trucks to records.
	b. Ante-mortem / Post-mortem	i. Potential Projects -
		ii. - Thermal Sensor (Live)
		iii. - Pre-warning of conditions for inspectors.
		iv. - Carcase inspection
	c. Post-mortem	i. - Need to test hypothesis the disposition of carcase is not going to change if post inspection also occurs in the Offal Room
		ii. - Odour detection
		iii. - Pathology classification vs consolidated condition.
		iv. - Potential for hyperspectral for Intramuscular Fat (IMF) & Lean Meat Yield) LMY – (Fat, yield traits)
		v. - Value in undertaking a baseline (e.g. 1 week) of liver status/performance.
		vi. - Voice Recognition for recording defects on an individual carcase basis.

		vii.	- Neurofibromas – hard to detect. Can train camera, mainly base of heart (not commonly seen, need VR for training).
		viii.	- Pack offal on site, investigate value proposition for carton screening. Recommend baseline as unsure of magnitude of the problem.
		ix.	- Identify impact / relationship of detection of individual organs and impact on full disposition
	d. Whole process	i.	- Baseline - Production costs for all diseases (even if sub clinical)
		ii.	- Do baseline (How, Cost, Business case, Payback). - Need analysis of "human" cost compared to "co-product" cost.
		iii.	- Need improved pathology/diagnosis (start with one organ then build up)
2. Beef	a. Ante-mortem	i.	- Investigate if foetus detection technology will operate on moving animal.
	b. Ante-mortem / Post-mortem	i.	- Identify / pre-detect carcase issues
		ii.	- Investigate if an elevated body temperature at point of arrival subsequently cools down.
	c. Post-mortem	i.	- Investigate microwave technology for density (e.g. lumpy skin).
		ii.	- Potential for AI models for lumpy skin (lesions may be hot depending on stage). Potential at hide puller.
3. Ovine	a. Ante-mortem	i.	- Sheep – confirm if thermal will work due to wool.
		ii.	- Automated counting of livestock on arrival. Significant value in matching counts of animals off trucks to records.
	b. Post-mortem	i.	- CLA – provide assistance to Meat Inspectors as condition are both visible and not visible.
		ii.	- OM for vaccinations, pussy pockets & cheesy gland.
		iii.	- Re-inspection for seeds post chilling.
		iv.	- Soft tissue tears are a significant issue (pelt pulling). Potential to include OM/cameras to scan carcase as a 'pre-warning' of soft tissue tears.
		v.	- Believe over detection of nephritis. Suggest review / baseline study to understand extent of the issue.
	c. Whole process	i.	- Develop an Animal Welfare score for a social license.

5. Appendix

7.1 Individual stakeholder feedback

Stakeholder	Topic	Stakeholder Feedback
1. Processor B [Beef]	**1. Potential Projects / Further Investigation**	- Need a study to identify individual organs' impact on full disposition.
		- Need to test hypothesis that not going to change disposition of carcase if post inspection once in Offal Room.
		- Odour detection important.
		- Investigate if an elevated body temperature at point of arrival subsequently cools down.
		- Value in matching counts of animals off trucks to records.
		- Investigate if foetus detection technology will operate on moving animal.
		- Neurofibromas – hard to detect. Can train camera, mainly base of heart (not commonly seen & need Virtual Reality for training)
		- Potential for AI models for lumpy skin (lesions may be hot depending on stage). Potential location at hide puller.
		- Investigate microwave technology for density (e.g. lumpy skin).
		- Potential for hyperspectral for IMF & LMY – (Fat, yield traits).
		- Potential Projects: - Thermal Sensor (Live). - Pre-warning of conditions for inspectors. - Carcase inspection.
		- Investigate potential for thermal imaging to assist in identifying lameness.
		- Need tool to identify if active or consolidated condition (potential to trim out).
	2. CODEX / Inspection	- Identify how to develop as an aid to assist buy-in by inspection systems. Expect a considerable amount of time/development required for performance to be equivalent to visual inspection.

3. Labour & OH&S	- Mental health a significant issue for inspectors, how to make role more engaging and desirable.
	- Vet skill retention a significant issue (competition from other organisations looking for similar skills).
4. Opportunity	- Opportunities for AI to identify anomalies from visual images, as a first step.
	- Opportunity for new odour detection technology to assist.
	- Need to understand potential role for OM and where it can assist and not compromise current inspection. Needs to provide short to medium term benefits.
5. Accuracy and specificity	- If a carcase is not fevered, few pathologies that will affect if fit for human consumption.
	- Need tool to identify if active or consolidated condition (potential to trim out).
	- Inspectors report postmortem findings, not diagnosis.
6. Febrile	- Investigate potential for AI & imaging to assist in identifying lameness.
	- Identifying where trucks go next (after carrying potentially febrile stock) is important.
	- If carcase is not fevered, few pathologies that will affect if an animal is fit for human consumption
7. Process flow	- Need to consider implications for detection once offal gets into the room after pre inspection. Understand if it changes disposition.
	- For EAD, need to identify if a load has a high incidence of febrile stock. Need alert to Livestock and the truck driver.
	- Offal presentation (e.g. encapsulated / unencapsulated) a significant issue.
	- Opportunity to have having technology at receivals / lairage and link to NVD
8. Biosecurity	- Incision required for C. Bovis however risk is low. Sporadic but mostly negative.
9. Enablers	- Significant opportunities linking hook tracking, UHF technology and surface detection technologies.
10. Location	- Pre-inspection - Value proposition from once an animal is in single file or carcase - At inspection - camera to pre-warn / screen.
	- Standardising presentation of lungs for inspection a challenge (also difference between plants).

		- Rectal temp undesirable due to OHS.
		- Hide puller (Sheep and Beef) is a suitable location where there the carcase ID is known and often clear visual access. - Carcase inspection station. - For beef, also immediately after the splitting saw.
		- Significant value in Vets having pre-warning for elevated thermal and lameness (ante mortem inspection.
		- Undesirable to have any additional restraints.
		- The further back in the process observations are made, the more difficult it is to link to an individual carcase.
		- Useful to measure temperature prior to trucking.
		- Contamination significant as entire offal sets (and briskets) lost due to being covered in ingesta/faeces. A significant issue with wagyu.
	11. Data Management & feedback	- Opportunity to leverage off Animal Health Data service (AHD) utilised by beef processor and a number of other feedlots.
2. Processor C [Lamb]	**1. Potential Projects / Further Investigation**	- Automated counting of livestock on arrival.
		- Re-inspection for seeds post chilling.
		- Believe over detection of nephritis. Suggest review to understand extent of the issue.
		- Provide assistance to Meat Inspectors as conditions are both visible and not visible.
		- Pathology classification vs consolidated condition.
		- Voice Recognition for recording defects on an individual carcase basis.
		- Pack offal on site, investigate value proposition for carton screening (downstairs). Recommend baseline as unsure of magnitude of the problem.
		- Animal Welfare score for a social license.
		- Identify / pre-detect carcase issues (potential for UHF Technology?)
		- OM to identify vaccinations, pussy pockets & cheesy gland.
		- Soft tissue tears are a significant issue (pelt pulling). Potential to include OM/cameras to scan carcases as a 'pre-warning' of soft tissue tears.

	- Can OM differentiate fat types and relationship to trained sensory?
2. Labour & OH&S	Pre-warning of potentially ripped skins useful to enable management of chain speed or manning levels.
3. Opportunity	- Opportunity to introduce new OM as a pre-warning of high defect incidence to Inspectors prior to the inspection station.
	- Potential live OM propositions - OM to detect issues on arrival and link to individual animal id (e.g. heat causing animal welfare issues)
4. Process flow	- Mob-based ante-mortem screening & pre-warning valuable - e.g. seeds, dog bites, soft skins. Can manage chain speed/manning.
	- Significant value proposition (big ticket items) if too muddy, dirty or seeds, return to vendor / sale yards.
	- Screening /detection of grass seeds prior to inspection important.
5. Enablers	- RFID, important to pair information to individual carcases.
	- Retaining rails works well with RFID and is reliably linked to carcases.
	- Implemented & integrated chiller sortation capability in 2018. Current limitation is sortation at full capacity.
6. Value proposition	- Contamination an important issue - useful to have method of detecting/measuring.
	- Pack offal on site, Value Proposition for carton screening. Some value for screening downstairs. Unsure of the magnitude of the issue.
	- Valuable to have rumen bolus detection
	- Value proposition if able to keep casings (intestines) longer), prevent loss of value. More in important in lambs.
	- Ante mortem inspection by Vet, in mornings, value to provide tools to assist.
	- Client benefit for OM and feedback providing accurate data and avoids over handling and over inspection.
	- New OM technology to assist inspectors on accuracy of disease classification and detecting sub-surface defects. Could OM be used to assist with AHD welfare score to provide more objectivity to GQL score.
	- Potential live OM propositions - to detect boluses in digestive tracts added by the farmers

		- Potential live OM propositions - foreign objects detection (e.g. ferrous vs non-ferrous metals)
		- Potential live OM propositions - pelt inspection (e.g. seeds)
		- Potential live OM propositions - Ante-mortem fit for processing
		- Potential live OM propositions - OM used to count livestock on load out. Counting is an issue whereby stockman and producer counts regularly don't match.
3. Processor A [Beef] & Meat Inspections Services A	**1. Potential Projects / Further Investigation**	- Small trial (intervention) - Small trial, identify if records align between feedlot vs plant offal).
		- Do baseline (How, Cost, Business case, Payback). Need analysis of "human" cost to "co-product" cost.
		- Baseline - Production costs for all diseases (even if sub clinical).
		- Need improved pathology/diagnosis (start with one organ then build up).
	2. CODEX / Inspection	- Standards require depth (palpation).
		- Major issue is how to sell benefits of new process (need hard & independent evidence to support claims).
	3. Process flow	- Critical to aid inspector doing their job on moving chain.
		- Lairage / receival includes: Receivals check, AQIS inspection, Condition Scoring.
	4. Data Management & feedback	- Provide animal Health feedback to all cattle (own & toll kill).
		- Offal yield reports monitored closely, however no centralised dashboard (Power BI)
	5. Value proposition	- Foreign objects are the biggest problem with significant value proposition for detection. All foreign objects are introduced in processing. Metal detection on offal chain and boning room. Particle size down to 2mm.
		- Value on removing "end of chain" FSMA. OM/Camera for gross pathology (inoculation, arthritis, broken ribs, ZTs [Zero Tolerance conditions). Can be anywhere after carcase is split.
	6. Payback	- Payback generally 12 months, consider 2 years if can demonstrate longer term value.
4. Meat Inspection Services	**1. Opportunity**	- Carcase inspection – significant opportunity compared with head and viscera

		- Head (Trachea for ingesta)
		- Liver (potentially easiest)
		- Opportunities for “Aided” or "augmented" inspection, however manual inspection won’t be replaced.
		- Viscera table
	2. Challenges	- Mechanics (and presentation), time, cost will be raised.
		- Kidney – no value.
		- Lungs – Presentation - Trachea attached/removed, trimming.
		- Presentation - Heart incised, kidney peeled.
		- Shape and size identification important.
		- Smell/odour important.
		- Lungs – Significant no. of issues e.g. Adhesions and not all human health issues.
		- Needs to address speed and odour (smell)
5. Processor D [Beef, Lamb]	**1. Potential Projects / Further Investigation**	- Value in undertaking a baseline (e.g. 1 week) of liver status/performance.
	2. Opportunity	- An opportunity map was produced for Live (ante-mortem) assessment
		- Validate if condemns are recorded – camera to detect green dye.
	3. Accuracy and specificity	- Detection rates decrease when supervised by QA.
		- Need for application of national standards.
	4. Process flow	- Pre-inspection will give inspectors more time for suspect carcases/items.
		- Animal Health data not recorded unless required by the customer.
	5. Data Management & feedback	- Report “kill” vs “pack” but not capture if trimmed or dropped.
	6. Value proposition	- Automated counting of livestock on arrival.
	7. Payback	- Generally two year payback.
	8. Adoption	- 1st module – test exceptions then when ok, then do all.
		- "Do everything for what you do"
		1. What do you need to inspect? 2. What technology does 100% of a piece?

6. Processor E [Canada, Pork]	**1. Potential Projects / Further Investigation**	- Rapid (online) method of iodine levels of fat (as Iodine levels can be used to indicate overall carcase fat firmness).
	2. Opportunity	- Objective measurement of meat colour and marbling for export markets (currently manually/subjectively accessed).
	3. Accuracy and specificity	- Performance criteria measure by complaints per million kg product shipped (e.g. 0.8 complaints / million kg shipped) - Biggest issue is bone-chips with rest of product not lending to foreign objects as sell whole products (other than potentially gloves).
	4. Challenges	- Installation of technologies severely constrained by space – facility has increased throughput by more than 6-fold since 2018 and cannot physically install desired automated systems for foreign object detection and loin quality assessment. Plans are progressing to construct a new facility in which provision will be made for objective measurement/automated systems.
	5. Data Management & feedback	- Total transparency (as business is predominantly farmer owned, no further processing) - farmers are provided feedback (manually assessed) on every load (e.g. present/absent for parasites and lung adhesions,).
	6. Value proposition	- Foreign bodies detection a major priority. Currently manually assessed and committed to automation/objective measurement. - Company is heavily committed to adoption of technologies: - Targeted world leading technologies when plant was constructed in 2018. - Use AutoFom for automated carcase grading/measurement. - Robotic head splitter Robotic splitting saw – significant reduction in ruptured abdomens due to it being a difficult manual task (new employees: ~30%, skilled employees: ~10%, robotics: 0.5%). - Improved quality and shelf due to robotics – less product handling, fewer bacteria, more space. - Business focus is both yield and quality as both result in dollar returns. Japanese market highly focussed on quality, opportunities for objective measurement to protect existing market/customers and open opportunity for new customers.
	7. Payback / Adoption Decisions	- Investment is cashflow dependent – buy or finance equipment for 5 yrs and amortise costs. Need to justify cost/benefit per hog.

	- Critical to see demonstration of new technology in operation at other sites.
	- Require written performance guarantee by service provider:
	  - What is the problem being solved?
	  - Meet performance criteria within +/- 3% (measure complaints e.g. 0.8 per million kg product shipped.

7.2 Point-in-Time Competitor Analysis (2024) – Imaging types, Australian presence and type, food industry operation, and Offal disease/defect detection

Region (HQ/Base)	Location (HQ/Base)	Types of imaging	Company	Australian Presence	Presence Type	Operates in Meat/Food space	Offal Disease / Defects Detection
1. Asia	a). China	i). Vision, X-ray & metal detectors	- Techik	N	N/A	Y	N
	b). Japan	i). High resolution X-ray line scan cameras	- Hamamatsu	Y	Distributor	Y	N
		ii). X-ray and metal detectors	- Anritsu	Y	Subsidiary	Y	N
2. Europe	a). Austria	i). Hyperspectral (Chemical Imaging Technology)	- InSort	N	N/A	N	N
	b). Denmark	i). Vision (shape, size, colour)	- JLI Vision	N	N/A	N	N
		ii). X-ray	- FOSS MeatMaster	Y	Subsidiary	Y	N
	c). Norway	i). Hyperspectral	- HySpex by Neo	Y	Distributor	Y	N
			- Maritech	Y	Subsidiary	Y	N
		ii). Multispectral & Hyperspectral sorting	- TOMRA	Y	Partnership	Y	N
	d). Spain	i). X-ray with multi-spectral capability	- Deep Detection	N	N/A	Y	N
	e). United Kingdom	i). Camera / vision with AI software	- Motion Ai (Automation Intelligence)	N	N/A	Y	N
		ii). X-ray	- Sapphire Inspection systems	N	N/A	Y	N
		iii). X-ray and metal detectors	- LOMA Systems	Y	Supplier/Partner	Y	N
	f). Iceland	i). X-ray, Spectra (Multi-spec), 2D/3D Camera	- Marel	Y	Subsidiary	Y	N
	g). Switzerland	i). X-ray + Vision	- Mettler Toledo	Y	Subsidiary	Y	N

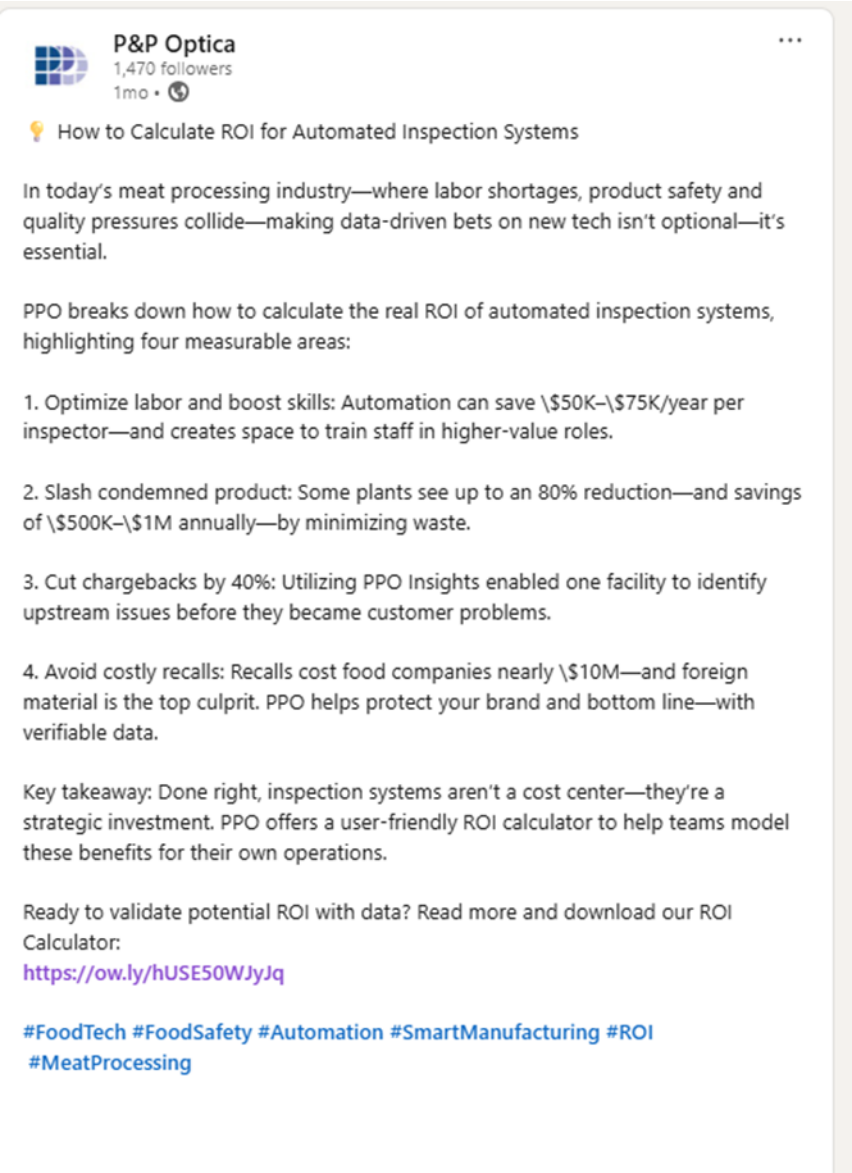
	h). Italy	i). Vision (in-package inspection)	- ViewTech	Y	Headquarters	Y	N
		ii). N/A	- PlantView	N	N/A	Y	N
	i). Germany	i). Machine Vision	- Basler	Y	Distributor	Y	N
		ii). Metal detectors, magnets, X-ray (for end of line)	- Sesotec	Y	Partnership	Y	N
		iii). Vision, X-ray & metal detectors	- Bizerba USA	Y	Subsidiary	Y	N
		iv). X-ray + Vision	- WIPOTEC	Y	Subsidiary	Y	N
		i). Hyperspectral & Machine Vision	- Frontmatec	Y	Partner & direct collaboration	Y	N
3. North America	a). USA	i). 2D & 3D imaging	- Cognex	Y	Offices / partners	Y	N
			- Landing AI	N	N/A	N	N
			- MARBLE Technologies	N	N/A	Y	N
			- Radiant Vision Systems	Y	Distributor	N	N
		ii). Analytics with AI with software solutions	- Power BI (Microsoft)	Y	Distributor	Y	N
		iii). Hyperspec - Nut application only / Vision system for meat	- Key Technology	Y	Subsidiary	Y	N
		iii). Hyperspectral	- HinaLea Imaging	N	N/A	Y	N
			- Impact Vision	N	N/A	N	N
			- Headwall Photonics	Y	Distributor	Y	N
		iv). Machine Vision	- SMART VISION WORKS (KPM)	Y	Distributor	Y	N
		v). Metal Detection	- Eriez Xtreme Metal Detectors	Y	Distributor	Y	N
		vi). Multi-Eye Hyperspectral and 2D (shape) / 3D (height)	- Eye Pro Systems (KPM Brand)	Y	Office/s	Y	N

	vii). Spectroscopy (FT-NIR)	- Bruker	Y	Office/s	Y	N
	viii). Vision - shape, size, color	- Neurala	N	N/A	Y	N
	ix). Vision (digital watermarks)	- Evrythng	Y	Subsidiary	Y	N
	x). Vision, X-ray & metal detectors	- TDI PackSys	N	N/A	Y	N
	xi). X-ray	- ISHIDA	Y	Distributor	Y	N
		- JBT	Y	Offices / warehouse	Y	N
	xii). X-Ray & CT	- FlexXray	N	N/A	Y	N
	xiii). X-ray / HD Camera	- ProSpection Solutions	Y	Headquarters	Y	N
	xiv). X-ray + AI (X-ray as a service)	- Greyscale AI	Y	Web-based	Y	N
	xv). X-ray and metal detectors	- A&D Inspection	Y	Office/s	Y	N
		- Rapiscan	Y	Distributor	Y	Y
	xvi). N/A (packaging solutions)	- SealedAir	Y	Offices / warehouse	Y	N
	xvii). N/A (Traceability, food safety compliance & supply chain transparency)	- Trustwell (formerly FoodLogiQ)	N	N/A	Y	N
	xviii). N/A	- Hygeiena (Sure Trend)	Y	Office/s	Y	N
		- Ignition	Y	Headquarters	Y	N
b). Canada	i). 2D/3D camera + Mulit-spec in P Series	- Sightline (KPM Brand)	Y	Office/s	Y	N
	ii). Colour camera	- UBI Meat Experts	Y	Marketing and trials (Pers Comm.)	Y	N
	iii). Hyperspectral	- P&P Optica	Y	Collaborator	Y	Y
		- MatrixSpec Solutions	N	N/A	Y	N

iv). Machine Vision	- Keyence	Y	Offices / warehouse	Y	N
v). Metal Detection	- Fortress Technology	Y	Distributor	Y	N
vi). X-ray	- ABM Equipment	Y	Headquarters	Y	N
	- Xray Reclaim	Y	Subsidiary	Y	N
vii). X-ray + Vision	- Lizotte Machine Vision	N	N/A	Y	N

7.3 PPO Return on Investment (ROI) Calculator

LinkedIn post (August 2025) and ROI calculator available at:
https://www.linkedin.com/posts/p%26p-optica_foodtech-foodsafety-automation-activity-7364312891098877953-VSTZ?utm_source=share&utm_medium=member_desktop&rcm=ACoAAAVSnRgBH6q6QttRAqnro5waD2yJuIsG6rI



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How to Calculate ROI for Automated Inspection Systems

In today's meat processing industry—where labor shortages, product safety and quality pressures collide—making data-driven bets on new tech isn't optional—it's essential.

PPO breaks down how to calculate the real ROI of automated inspection systems, highlighting four measurable areas:

1. Optimize labor and boost skills: Automation can save \$50K–\$75K/year per inspector—and creates space to train staff in higher-value roles.

2. Slash condemned product: Some plants see up to an 80% reduction—and savings of \$500K–\$1M annually—by minimizing waste.

3. Cut chargebacks by 40%: Utilizing PPO Insights enabled one facility to identify upstream issues before they became customer problems.

4. Avoid costly recalls: Recalls cost food companies nearly \$10M—and foreign material is the top culprit. PPO helps protect your brand and bottom line—with verifiable data.

Key takeaway: Done right, inspection systems aren't a cost center—they're a strategic investment. PPO offers a user-friendly ROI calculator to help teams model these benefits for their own operations.

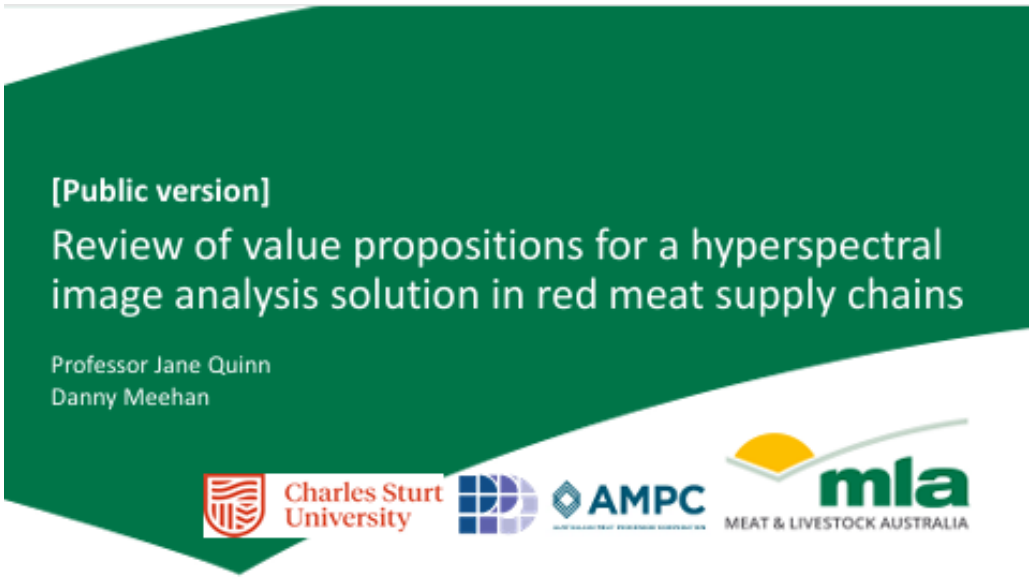
Ready to validate potential ROI with data? Read more and download our ROI Calculator:
https://ow.ly/hUSE50WJyJq

#FoodTech #FoodSafety #Automation #SmartManufacturing #ROI #MeatProcessing

PPO Return on Investment calculator:

PPO_ROI-Calculator-for-blog-post-2024_20

7.4 Industry PPT Deck: Summary



1. Background

- Current offal health monitoring in abattoirs relies on visual & manual assessment by meat inspectors.
- Costly as requires trained personnel.
- Disease conditions & contamination managed either by trimming affected product, downgrading, or disposal.
- Inspection is a requirement for export status.
- Labour costs may make routine inspection outcome recording financially unviable in smaller businesses.
- Challenges:
  - Data generated from manual scoring process is not routinely recorded in all abattoirs.
  - Inspection criteria can be inconsistently applied between sites & personnel.
  - ➢ **RESULT - inconsistent data collection across the industry.**
- Whilst current inspection process is robust & service delivery is reliable:
  - Increasingly significant industry shortage of inspectors.
  - Increasing requirements for product surveillance, provenance & integrity reporting.
  - ➢ **OPPORTUNITY - an environment where attenuated inspection may be a desirable industry option.**

2. Objectives

- Specific objectives:
  - Desktop exercise collecting & collating insights & benefits on potential applications of technical solutions in red meat industry from:
    - Existing commercial installations (PPO); and
    - In-kind red meat processing partners.
  - Review of competitor technology applications.
  - Collection & reporting of insights on potential red meat applications of technical analysis solutions. Gathered through:
    - Series of interviews of current users in commercial manufacturing applications in USA, Canada and Europe; and
    - Site visits of in-kind beef and lamb processing partners.
  - Development of an investment R&D roadmap & summary findings presented to the project steering group & in-kind partners.

3. Methodology

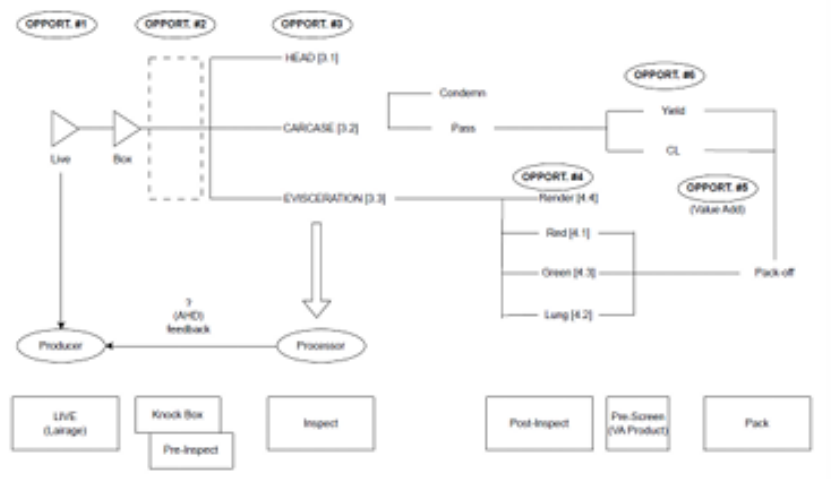
1. Project planning & scheduling
2. Discovery exercise
   - Engagement framework developed as to guide discussions.
   - Site visits to gain insights & understand:
     - Potential benefits, implications & propositions of existing & potential technical solutions in relation to animal health & disease.
     - The use of human inspectors & how their skills are used / applied at each location.
   - Aims of discovery & analysis:
     - Understand where & how support can be provided to meat inspectors.
     - How improved utilisation & extraction of value (from technical solutions) of animal health/disease & offal product status & pricing models can be achieved.
   - Participants:
     - 1x lamb processor, 3x beef processors, 1x pork processor (Canada), 1x independent meat inspection provider.
3. Review relevant Australian meat inspection standards
   - Review AS 4696:2023 "Hygienic production and transportation of meat and meat products for human consumption" regarding inspection requirements for offal, carcase and beef heads.
   - Aimed to identify:
     - Requirements/considerations for use of objective measurements/devices to augment/undertake meat inspection activities (focus on compliance & operational factors).
     - Opportunities for application of objective measurement technologies in ante-mortem inspection were also identified & included in scope of this review.
4. Competitor/Technology Analysis

4. Results/key findings – In-Plant opportunities

1. Discovery approach involving open discussions (with broad range of internal processor stakeholders) & site inspections/walk-throughs proved extremely valuable:
   - Gained insights, potential benefits & practical implications/propositions of existing & potential technical solutions in relation to animal health & disease.
   - Reinforced observations indicating that different stakeholders have different focus/value of the same data within a business.
2. Plant-walk throughs with key site personnel & observation of inspection processes (ante and postmortem) & offal processing were particularly valuable:
   - Identified physical locations on processing line &/or infrastructure where installed devices may:
     - add value to plant's operation and inspection processes.
     - assist / provide support to meat inspectors.
     - Refer slides #6 & #7 respectively for generic opportunity maps for beef and lamb processing plants.
3. All stakeholders identified how technical solutions could support meat inspectors & improve utilisation and extraction of value of animal health/disease & offal product status.
4. A significant number of opportunities, potential projects & areas for further investigation were identified.
5. Extraction of additional value from existing technologies was a priority before adoption of new technologies.

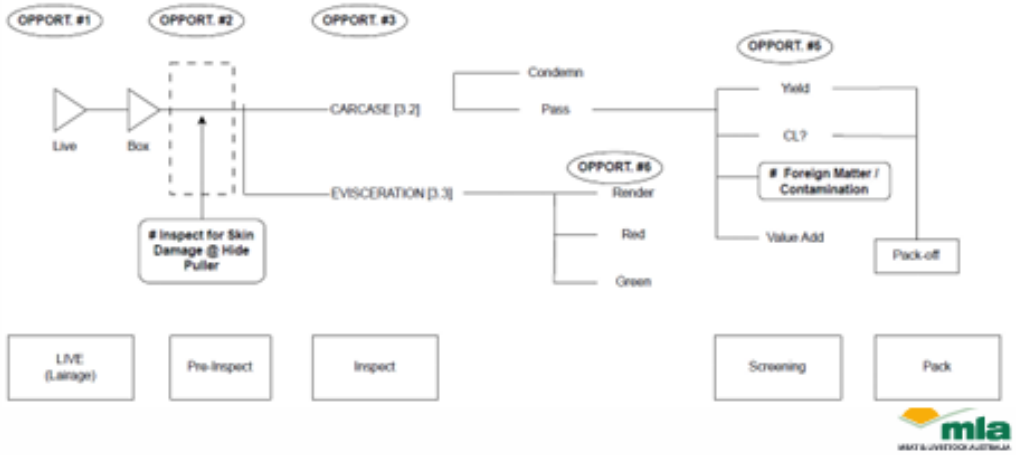
5. Results/key findings – In-Plant opportunities

Beef – Preliminary Opportunities Map



6. Results/key findings – In-Plant opportunities

Sheep / Small-Srock – Preliminary Opportunities Map



7. Results/key findings – Standards Review

1. Under current Aust. meat inspection standards (AS 4696:2023), technologies are unable to replace Meat Safety Inspectors & manual inspection procedures due to the Standards specifying:
   - Meat Safety Inspector **must be present** during slaughter; and dressing of each animal; and
   - A number of **inspection activities** require **manual procedures (e.g. palpation, incision and odour)**.
2. Under current standards, **opportunity for technologies** to provide:
   - **Pre-inspection status** of conditions to the Meat Inspector,
   - However the **Meat Safety Inspector must inspect** the carcase or carcase part in accordance with the standards.
3. **Location** of **assistive technologies prior** to the **Meat Safety Inspector** will:
   - Enable provision of information to the Meat Safety Inspector to **augment their inspection**
   - However a **value proposition for efficiency & cost effectiveness needs consideration**.
4. **Opportunities exist** (pending meeting performance criteria) for **technologies** to **augment Meat Safety Inspectors' inspection** activities.
5. Standards state that carcase & carcase parts are not to leave the Slaughter Floor until a post-mortem disposition is applied.
   - This requirement requires **further consideration if subsequent inspection** outcomes by devices with **higher specificity/granularity for offals differ** from the **final on-floor disposition outcomes** based on human inspection outcomes.
6. Requirements within the Standards also identified **device design & integration considerations**.
7. **Potential amendments to CODEX** to **enable commencement of adoption of technical solutions** suggested.
   - Consider investigation of EU model where auxiliary inspection is utilised for pig, poultry, and bovine.

8. Results/key findings – Competitor / Technology Analysis

1. **Significant number** of **technologies** in use throughout the **international** meat processing industries **primarily focus on foreign matter (FM) detection.**
2. **Foreign matter identified as a key priority** for the application of technology solutions above objective assessment of quality traits.
   - Due to significant value proposition and / or impact on business recalls / market access imperatives of FM.
3. Technology provider numbers operating in the Asia-Pacific is small compared to North America / Canada or Europe.
   - **Lack of co-locality suggests challenges for processor uptake / access to multiple solutions in local market**.
4. **PPO's hyperspectral system** is the **only system** identified providing **technical solutions for animal health/disease & offal product status.**
5. Observations re. adoption of new technologies include:
   - Improvement in accuracy of chemical lean measurement (based on hyperspectral assessment) appear to not be a high priority for customers.
   - Therefore difficult establish initial customer base & sites to demonstrate value in a real-world settings.
   - While application of technical solutions for quality assessment may be successful, progress towards commercializing a new application of technologies can fail due to:
     - Practical reasons - footprint, product traceability, environment, etc.
     - Lack of a clear business proposition - cost, ROI.
     - Lack of planning for integration / implementation.

9. Benefits to Industry

1. All stakeholders identified how technical solutions could support meat inspectors and improve utilisation & extraction of value of animal health/disease & offal product status.
2. Benefits to industry include:
   - Significant opportunities for technologies to assist inspectors perform roles **more efficiently rather than replacement of inspectors.**
   - New Objective Measurement (OM) technology to assist inspectors with **more accurate disease classification & detecting sub-surface defects.**
   - Opportunity to **increase utilisation & leverage from On-site Veterinarians' significant training in public health & corporate knowledge**
     - Improve disease surveillance & add value.
   - Opportunities for processors to **gain more value (e.g. supplier feedback)** through **more granular (accurate) inspection data.**
   - The provision/feedback of **more accurate & consistent detection of animal health/disease status**:
     - **Enables livestock suppliers** to **implement on-farm/transport practices** to deliver a **better quality product.**
   - **Processors** welcome **more objective measures to support & expand** their **current grid payment system with producers.**
     - Specifically, additional measures of value traits **including animal health disease and carcase & offal inspection.**
   - Value in **Animal Health data being with a single entity** to **enable a full history** to be observed (**disease patterns** etc.)
     - **Role for MLA to assist producers in data interpretation** (or to direct producers to third-party providers/data aggregators for analysis and action).
   - **Significant value of information that is collected/verified/accurate**
     - an expect significant cost incurred by over-inspection.
3. *Quantification of benefits of the objective measurement of offals was outside the scope of this project and is the focus of other MLA projects.*

10. Potential projects / further investigations

Species	Location	Comments Summary
1. All	a. Ante-mortem	Investigate potential for thermal imaging to assist in identifying fever / inflammation.
		Value in matching counts of animals off trucks to records.
	b. Ante-mortem / Post-mortem	Potential Projects -
		- Thermal Sensor (Live)
		- Pre-warning of conditions for inspectors.
		- Carcase inspection
	c. Post-mortem	Need to test hypothesis the disposition of carcase is not going to change if post inspection also occurs in the Offal Room
		Odour detection
		Pathology classification vs consolidated condition.
		Potential for hyperspectral for Intramuscular Fat (IMF) & Lean Meat Yield| LMY – (Fat, yield traits)
		Value in undertaking a baseline (e.g. 1 week) of liver status/performance.
		Voice Recognition for recording defects on an individual carcase basis.
		Neurofibromas – hard to detect. Can train camera, mainly base of heart (not commonly seen, need VR for training).
		Pack offal on site, investigate value proposition for carton screening. Recommend baseline as unsure of magnitude of the problem.
		Identify impact / relationship of detection of individual organs and impact on full disposition
	d. Whole process	Baseline - Production costs for all diseases (even if sub clinical)
		Do baseline (How, Cost, Business case, Payback). - Need analysis of "human" cost compared to "co-product" cost.
		Need improved pathology/diagnosis (start with one organ then build up)

11. Potential projects / further investigations (cont'd)

Species	Location	Comments Summary
2. Beef	a. Ante-mortem	Investigate if foetus detection technology will operate on moving animal.
	b. Ante-mortem / Post-mortem	Identify / pre-detect carcase issues
		Investigate if an elevated body temperature at point of arrival subsequently cools down.
	c. Post-mortem	Investigate microwave technology for density (e.g. lumpy skin).
		Potential for AI models for lumpy skin (lesions may be hot depending on stage). Potential at hide puller.
3. Ovine	a. Ante-mortem	Sheep – confirm if thermal will work due to wool.
		Automated counting of livestock on arrival. Significant value in matching counts of animals off trucks to records.
	b. Post-mortem	Provide assistance to Meat Inspectors as condition are both visible and not visible.
		OM for vaccinations, pussy pockets & cheesy gland.
		Re-inspection for seeds post chilling.
		Soft tissue tears are a significant issue (pelt pulling). Potential to include OM/cameras to scan carcase as a "pre-warning" of soft tissue tears.
		Believe over detection of nephritis. Suggest review / baseline study to understand extent of the issue.
	c. Whole process	Develop an Animal Welfare score for a social license.