final report

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Evaluation of processing methods and vision systems for detection of low density foreign object contamination

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Abstract

The primary objective of this project is to evaluate and test processing and detection methods aimed at eliminating low density foreign object contamination which may have inadvertently entered the supply chain.

This final report covers all phases of the project from desktop study to the installation and commissioning of the low density contaminant vision detection system, including pre-production trialling and testing. Significant progress and learnings have been made by completing the installation and validating the system in its intended production environment.

Successful implementation of this technology will help reduce the risk of contamination in mince production and minimise the chances of major consumer hazards, product recalls, and reputational brand damage.

This final report is consistent with the significant work completed in this project. It is noted the key deliverables achieved within the project are:

- Validation of the Dyna CQ system design to ensure it covers all requirements of site operations.
- Planning and installation of the DynaCQ system.
- Startup, commissioning, and pre-production validation of the system on a red meat mince production line.
- Training of operators to allow monitoring and interpretation of detection events.
- Optimisation of the vision system.
- Development and implementation of Periodic Validation Program to ensure the integrity of the DynaCQ system over an extended period.
- Ensure all recommendations are captured to further enhance the chances of foreign object detection and Good Manufacturing Practices.

This technology has been developed and successfully trialled with the Danish Meat Research Institute (DMRI) and the project team. Installation, commissioning, and production trials on the modified prototype have allowed validation and further insights into the potential benefits of this technology.

Executive summary

Mince contamination from low density polymers in the feed stream poses a risk to consumers and can result in significant brand damage. RROA has completed a project to install a new vision system capable of detecting the presence of surface contaminants as small as 1.5mm x 1.5mm. This technology was developed and successfully trialled with the Danish Meat Research Institute (DMRI) and the RROA project team. Following initial pilot scale trials, a modified prototype was installed and commissioned to perform production trials and testing in a production environment.

RROA has installed the new vision detection system on the mince infeed conveyor. This system will inspect 100% of the visible surface of all red meat material being fed to the main mince lines to reduce the risk of low density polymer contaminants entering the mixers. The system is functional and performance monitoring is ongoing to ensure optimal detection thresholds are achieved. This has and continues to involve the development and fine tuning of the detection algorithms. These need to be adjusted to the specific nature of the application and its environment, sample contaminants are used to trigger detection and 'train' the system.

Photo E2: DynaCQ system installed on conveyor line at RROA

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1 Background

Low density foreign objects have been known to occasionally be found during incoming manual quality inspection of raw material destined for mince production. The risk such contamination poses to food safety has triggered an investigation into the potential continuous inspection solutions available for the Australian Red Meat Industry.

Throughout the supply chain, cardboard and plastic films are widely used to package and transport food ingredients and finished products. In red meat processing specifically, raw material is typically supplied in cartons of vacuum sealed low density polymer bags. There is a risk that small pieces from these materials and other items used in handling the meat may inadvertently enter the supply chain in primary processing through accidental means or poor handling practices. These include cardboard pieces, fragments from plastic conveyor chains, and torn pieces from plastic bags used to package the meat or line the storage pallecon bins. Due to its many uses in direct contact with the meat, low density polyethylene film (poly) poses the highest risk of contamination.

Even if detected early, an incidence of poly entrapment could cause significant material and productivity losses. If undetected, such foreign object contamination would also pose a potential risk to consumers and may result in product recalls and reputational brand damage.

Although low density materials such as plastic and paper are used extensively in food handling and production, they cannot be easily detected usingconventional technologies for foreign body detection. Even the most advanced x-ray and metal detectors can only detect high-density materials and metals. Reliance on visual inspection by trained operators is common practice, whilst it does provide some risk reduction, this alone is prone to misses due to human error and the limitations of human vision on size and colour perception.

Recent technological advancements in sensing technologies, combined with high speed computing capability, have made possible the design of powerful new detection systems. High speed image processing has been identified as a possible solution for detection of low density contaminants present on the surface of meat.

The application of such detection technology solution with red meat inspection will be the first of its kind in Australia, it will provide a new quality control point (QCP) and enhance the current quality assurance checks which already include temperature control monitoring and metal detection. This will further guarantee product integrity of ground or diced Australian red meat products.

2 Project objectives

The primary objective of this project is to evaluate processing and detection methods to eliminate or reduce the risk of low density foreign object contaminants in raw material from entering the red meat mince production process operations.

The specific objectives of the project are:

- Desktop study exercise to determine available sensing technologies and processing interventions to detect and reduce or eliminate the incidences of poly entrapment.
- Develop and undertake travel plan and preliminary trial plans to evaluate sensing equipment with global technology providers.
- Commission selected equipment at Retail Ready Operations, test and validate over an extended period.
- Develop an internal business case for implementation of sensing and/or intervention technologies to reduce/eliminate the risk of low density polymer contamination.
- Present a report of findings on commercial testing and recommendations presented to RROA senior management for long-term strategies to significantly reduce / eliminate low density foreign object contamination in red meat products.

The expected outcome will be validated and adapt global solutions in terms of sensing and/or processing interventions to significantly reduce or eliminate low density foreign object contamination in red meat products.

The RROA team collaboratively developed a project specification that identified the following as the key objectives for the program:

1. Evaluate the cost impact of potential contamination to RROA business.
2. Define equipment specification requirements for the technology capable of low density poly contamination detection in red meat.
3. Research and review technology solutions, concluding in selection of a preferred solution.
4. Document tests and trials required to confirm a technical solution for low density poly contamination in an onsite production trial.
5. Conduct & document on site production trials of the selected technical solution.
6. Report outcomes of preferred technology solution.

3 Methodology

The scope of this project will be undertaken in the following stages:

3.1 Desktop review, travel plan and preliminary trial design

The initial pre-scoping and planning exercise will involve RROA to engage with Danish Meat Research Institute to research possible products and technologies available for detection of low density contaminants. RROA and Danish Meat Research Institute will undertake a desktop review of potential solutions and test for suitability of an on-line inspection system that will detect low density contamination. The key to success will be the research and investigation process to ensure the technologies are suitable to detect a variety of possible contaminants.

In partnership with Danish Meat Research Institute a research, a development and validation program will be created to discover and validate a system with the objective of ensuring comminuted products such as mince can be monitored for low density contamination with the application of the system. RROA and DMRI will work together to select and validate a system at the DMRI lab that will meet the requirements of the Australian red meat industry.
A number of global service providers including DMRI will be engaged to organise a number of site visits to enable RROA to optimise machine location and operation to guarantee optimal surface inspection of the product. A discovery tour travel plan will be developed. For those providers where pilot plant testing is possible, a preliminary testing plan will be scoped as part of the study tour.

The expected outcomes of the initial pre-scoping phase will be:

- Develop a Research and Development program to identify key objectives required by RROA
- Research and document meat specifications that are supplied from various suppliers
- Research and document potential contamination risks that the Australian red meat industry faces
- Gather samples of potential contaminations that the Australian red meat industry faces
- Discovery meeting which covers the possibilities of what machines and vision system technologies are available
- RROA and Danish Meat Research Institute prepare initial testing schedule

A RROA & MLA project work group will be assigned to the project to evaluate progress including oversight of milestones and final reports. The progress report on outcomes of the desktop review and travel and preliminary trial plans submitted and approved by RROA & MLA project group.

3.2 Discovery exercise of processing and detection methods. Preliminary trials at global testing sites

This will involve the RROA project manager traveling to global sensing and technology providers including Danish Meat Research Institute. A series of pre-planned short-term pilot plant trials will be undertaken in DMRI test facilities using sensing equipment to conduct initial short term testing validations using potential red meat contaminants. Prior to lab testing, a DMRI site visit will be required to identify the ideal product presentation and ensure optimal surface inspection. Pre-planning exercises with DRMI technical experts will identify the spectral image range that is required for optimal resolution of contaminations and detection of all possible contaminations including trials to detect clear plastics.

The progress report on the detailed work schedule and outcomes of the study tour are to be submitted by DMRI and accepted by RROA & MLA project group.

This forms a critical Go / No Go project decision point where the outcomes of Stages 1 & 2 will be assessed by the project review group. A successful assessment will result in approval to progress to stage 3 and RROA to order the required prototype DMRI sensing equipment. The outcome of the project will trigger a review of the staged R&D approach and associated budget.

3.3 Commissioning and production testing at RROA

This stage aims to progress the study to production environment testing of the selected technology. The system will be installed, commissioned, and integrated with the existing production line at RROA. DMRI will be on site to assist with finalising the installation and perform production tests. RROA and DMRI will develop a validation test criteria to confirm the systems suitability and ensure the requirements are met for the Australian red meat industry. RROA and DMRI will develop an integration plan for the online inspection of up to 50% of Australian mince that will be monitored for low density contamination. RROA and DMRI will develop and design the system to guarantee ideal product presentation to ensure optimal surface inspection. RROA will order the prototype sensing equipment, freighted to RROA and commissioned by RROA with technical input provided by DMRI.
On-line production testing of the system will detect and prevent disruption to processing equipment, reduce the chances of major consumer hazards and prevent product recalls and reputational brand damage.

This stage will include:

- Develop a testing and validation program to identify key objectives required by RROA
- Testing program will include current RROA conditions such as belt speeds, room temperature and meat specifications.
- Danish Meat Research Institute to conduct testing validations in the DMRI lab using the Australian red meat contaminations and RROA conditions.
- Danish Meat Research Institute to report on and document the validation program.
- RROA to lease the low density contamination vision system
- RROA and Danish Meat Research Institute to develop a project installation plan and commissioning/validation schedule
- RROA to supply services to the low density contamination vision system
- RROA to mount the low density contamination vision system
- RROA and Danish Meat Research Institute commission and validate the system
- Danish Meat Research Institute to develop a periodic validation program to ensure the integrity of the system
- RROA to implement the periodic validation program to ensure the integrity of the system and record all results
- RROA to integrate the automatic reject system if installed at the reject station

Progress report to be submitted to and accepted by RROA & MLA project group.

3.4 Report & recommendations to RROA and wider industry

A final RROA company report to be developed in consultation with DRMI technical advisor(s) shall include:

- Desktop review of sensors and processing technologies.
- Travel plan & outcomes of preliminary trial work at DMRI
- Finding of commercial validation
- Recommendation to RROA & wider industry

- A production report with all on-line testing results will be compiled, documented and shared with the Australian Red Meat industry.
- RROA and Danish Meat Research Institute will also include recommendations for the Australian Red Meat industry.
- RROA will supply edited machine footage highlighting low density and detection, validation testing and online inspections.

A RROA approved industry report to include:

- Outcomes of desktop study
- General description of innovations in technologies, process and packaging with defined targeted from the discovery exercises
- Recommendations to wider industry.

4 Results

4.1 Research & Document RROA Packaged Meat Specifications

The nature of the minced meat production process and its level of automation has led to the decision to focus the project on this red meat production process. Product specifications were analysed for differences that may impact contamination detection.

Minced meat products represent a considerable weekly volume, besides the different species including beef, pork, lamb and some blended products, the major variable is fat content as indicated by the 3, 4, or 5 Star designation.

4.2 Research and Document Potential Risk of Contamination faced by the Australian Red Meat Industry

4.2.1 Reducing the Risk of Contamination

The value proposition for the Australian red meat industry is the implementation of a new innovative low density contamination detection system with the following benefits:

- Ensure consistent and contamination free products for the consumer
- Reduced risk of product waste due to low density contamination.
- Reduced risk of product re-sorting due to low density contamination.
- Reduced cost/penalties on suppliers due to detection of low density contamination.
- Provide feedback to upstream processes and suppliers in the event of contamination.
- Reduced risk of impact on retail stores by earlier detection and elimination of low density contamination.

It is general common knowledge in the industry that individual incidences can cost companies in excess of $250,000 and additional reputational damages. In instances where product recalls are required, estimates provided to MLA are in excess of several thousands of dollars. Due to such incidents, some companies have had to deploy additional labour units (2-4) to visually inspect every batch at significant cost to the processor.

4.2.2 Risks of contamination

In food processing, the risk of foreign object contamination exists as soon as any ingredient or product is put into contact with surfaces, handling and processing equipment, storage containers, etc. In meat processing the equipment and handling materials are the main potential sources of contamination risk. Inline metal detectors can detect and reject any product containing metal pieces as small as 4mm.

There is typically no inspection equipment capable of detecting low density polymer contamination. The most likely sources of low density polymer contamination are:

- Bin Liner from suppliers
- Vacuum bags from raw material packaging
- Cut bin liner

Figure 3: Meat destined for mince processing in plastic bin liner

Plastic liners and bags are commonly used throughout the primary and secondary operations for primary handling, packaging, storage, and transfer to secondary production. Meat supplied to the mince process is typically stored in bins lined with plastic bags.

This, combined with the fact that a portion of the meat for mince is sourced from trim material which has therefore undergone additional handling in primary processing puts the mince lines at the highest risk of occurrence for a low density poly contamination issues. This guided the research work towards using minced meat and the mince processing line as the bases for testing and trial work.

4.3 Defining Requirements

Retail Ready Operations have set out a strategy to support defining and specifying what is required of a Low Density Foreign Object detection solution. This strategy included:

- Gathering information of the range of meat specifications and their potential impact on contamination detection in relation to a change in colour, moisture.
- Develop a high level User Requirement Specification to inform suppliers what Retail Ready Operations requirements are to ensure that the technology provides the best chance to detect foreign objects, thereby achieving the highest level of protection against product recalls and loss of product.
- Establish key objectives for the overall project, with collaboration between the Manufacturing, Engineering and Quality Control departments.
- Reviewing the technological quality - hygienic design and technological stability of the measuring unit, both at DMRI and also in the Danish Industry where some installations have been used for several years and many on 2 shift operations.

4.4 Selection of Technology

Retail Ready Operations has completed initial discovery meetings and product reviews with DMRI. Several integrators were contacted and a discussion around standard RGB camera technology and the challenges they face with low density transparent product detection has concluded that they would not be effective on the types of contamination expected. The detection of low density transparent contaminations is complex and requires a bespoke and flexible solution for the red meat industry.

Retail Ready Operations with the guidance of Niels Madsen from the "Danish Meat Research Institute" have investigated possible solutions for detection of low density contaminations. Danish Meat Research Institute is testing a spectral camera which alters the spectral range of a specialised camera allowing the low density transparent contamination detection to become possible. This technology will need to be combined with high speed vision processing detection of small surface contamination at a line speed of 60m/min to ensure its feasibility in the red meat industry. As part of the review, Retail Ready Operations will investigate further options to determine if other contaminants can be detected with oscillating spectral ranges.

Meetings and discussions were held between RROA Engineering team and the DMRI team regarding the technologies available and the benefits that were provided by spectral camera and imaging technology. It was agreed that systems such as the DYANCQ appeared to provide the technology required to detect low density poly contaminations as specified by RROA.

The DynaCQ style of technology analyses image data captured on-the-fly and detects even minuscule unwanted objects on the product surface (down to 1.5x1.5mm). With this type of technology for quality inspection a reject system can be coupled with it prevent contaminated products from travelling further down a line. Stored images can be used for documentation and root cause analysis. Refer to DynaCQ info sheet in Appendix 8.1

4.5 Other Detection Methods Considered

4.5.1 Microwave detection methods

Some considerations of alternative detection methods are being reviewed and evaluated concurrently to the current DMRI sensing method. Initial considerations from engaging with the service provider of a microwave detection method (under R&D development and evaluation):

- Dr. Jayaseelan Marimuthu is a Research Fellow at Murdoch University and working with MLA as the Operational Manager of the Advanced Livestock Measurement Technologies program (ALMTech is a 4-year R&D program co-funded by a Federal Govt. grant under their Rural R&D for Profit program). Jaya has expertise in microwave applications and has made good progress with a handheld prototype to measure carcase fat depth
- Size of the pieces of plastic in the mince generally looking to detect low density contamination upwards of 1.5mm by 1.5mm
- Seeded poly contamination will be randomly placed on the surface of trim. The pallecon will be tipped into a hopper and metered onto a 600mm below running at 30m/min
- Critical dimension to cover scanning is approximately 600mm wide @ 30m/min
- DMRI claim their solution is capable of detecting a minimum foreign object > = 1.5mm by 1.5mm.
- An R&D application is under development (expected that MLA will receive in 2019) to support alternative detection methods including microwave detection.

4.5.2 MEXA DV technology

MLA consulted with current global provider (Ed Morton) Rapiscan Systems. Below are some of the initial considerations using X-ray technology to detect low density polymers in meat:

- Uncertain that X-ray will be effective. The radiographic contrast in a thin plastic film is low and considered that it would be very hard to calibrate a system to find this reliably.
- However, the good thing about plastic, rather than meat, is that it has a very different conductivity (low for plastic, high for meat). Considered that this may form the basis of a measurement using very high frequency (THz) microwave or maybe mid-IR frequencies.
- Perhaps, as a start, use the hyperspectral camera in the proposed offal screening program and add a work package to this program on plastic film detection for both contamination detection and film integrity during the packaging process?
- It is proposed that there may be somewhere in the spectrum where the minced beef is somewhat transparent and the plastic will be somewhat attenuating. In this case, there may be an opportunity to detect sufficient contrast to produce a sensible result.

4.6 Initial Testing Validation Schedule

Retail Ready Operations have internally developed a validation program between Retail Ready Operations Quality Assurance and Engineering team. The schedule has been developed covering product varieties and different low density foreign object contaminations. The testing has been conducted across the following types of plastic and other contaminants;

- Dark Blue Plastic Bin Liner
- Transparent Blue Plastic Bin Liner
- Transparent Green Plastic Bin Liner
- Rubber Gloves
- Aprons
- Long Rubber Gloves
- Plastic from Sensors
- Conveyor Belt Shavings / Pieces
- Hair Nets
- Earplugs

Testing was also done across a large array of contaminant sizes and percentage of the foreign object embedment in the product representing variation in raw material, presentation and level of fat. A sample of these test conditions is noted below.

- Test 1 Place the contamination on the top surface of the meat - 100mm x 100mm piece of contamination.
- Test 2 Place the contamination on the conveyor and place meat on top of the - 100mm x 100mm piece of contamination.
- Test 3 Partially embed a - 100mm x 100mm piece of contamination.
- Test 4 Embed 80% of the - 100mm x 100mm piece of contamination.
- Test 5 Embed 90% with the 10% being perpendicular to the conveyor - 100mm x 100mm piece of contamination.
- Test 6 Wet the Plastic and Meat - Embed 80% of the - 100mm x 100mm piece of contamination.

The tests also need to be done in an environment that is similar to the RROA plant conditions to ensure the results are transferable to actual production conditions. Environmental conditions that will be applied when testing are:

- Testing Environment Condition 1 Conveyor speed is to be configured to RROA.
- Testing Environment Condition 2 Product Spread to be similar to current production.

4.7 On Site Review of Existing DynaCQ Installations

Due to the technical and fundamental image processing methods behind the proposed system, Retail Ready Operations needs to ensure that its product presentation is optimised to ensure optimal surface detection is achieved.

Retail Ready Operations project manager in conjunction with DMRI travelled to two large producers to understand the process flow to ensure the Dyna CQ solution is installed in the optimal position. A total of four units installed over existing belts on different product types, all high speed belts running 30-60 metres per minute were reviewed in detail. Examples of typical detection were presented with very small fragments being the most common incidence. Three lines used manual reject scenarios as intended with RROA whereas one required automatic reject implemented with a diverting belt. All solutions prevented plastic items to continue in the product stream and reduced the risk of reaching the consumer.

The following key points are vital to ensure optimal surface inspection:

- Optimisation of the current line speed to essentially pull product away from the infeed hoppers. RROA and DMRI have predicted that a 20% increase of line speed will achieve optimal product presentation. This will take the current inspection conveyor speed from 30m/min to 42.5m/min. This will be achieved by modifications to the current control system. As feasible the system modification of belt speed will be designed for even higher speed as necessary to obtain single layer presentation. The belt control will as feasible ramp up and down speed of belt at detection to secure minimum movement of the detected FO and thereby easy removal by the process operator
- Upgrade the current conveyor drum motor to a drum motor with an inbuilt encoder with a minimum encoder resolution of 10 pulses per mm.
- RROA and DMRI reviewed the current line and modifications will need to be made to ensure when the line stops all conveyors stop in a synchronized manner. This will ensure we do not overload the main inspection conveyor.
- The Inspection system will be installed prior to the first grind station for early detection. This has been agreed between both parties as it gives the best chance to find and remove a foreign object pre-grind. A later positioning may implicate down-sizing the foreign object and may also implicate more product when removing the foreign object
- Retail Ready Operations have requested two options when a contaminant is detected and the conveyor has stopped;
    - **Option 1** will allow operations to acknowledge the detection as 'Product OK' (indicating a false positive) or 'Object Removed' after clearing the contaminant and inspecting the product

- **Option 2** will allow operations to select a 'Clear Conveyor' function which will reverse the conveyor and dump the contaminated product into a reject bin. This can be relevant at large detection levels.

In summary the proposed location for the Dyna CQ system has been placed prior to the first grind station. This will ensure Retails Ready Operations best chance in detection of Surface only Low Density Foreign Object contamination as the contamination in majority of cases will offer a larger surface area. Additional line optimisations on belt speed and necessary screens will be completed to ensure the optimal product spread is achieved to lower the chances of product covering the Low Density Foreign Object contamination. If the Dyna CQ system was to be installed downstream of the first grind station, there would be a higher possibility of the Low Density Foreign Object contamination becoming embedded in the product.

The below image (Figure 1) provides a layout of the current system including the line layout. The Dyna CQ has been proposed to be installed between the metal detector and the first stage grinder.

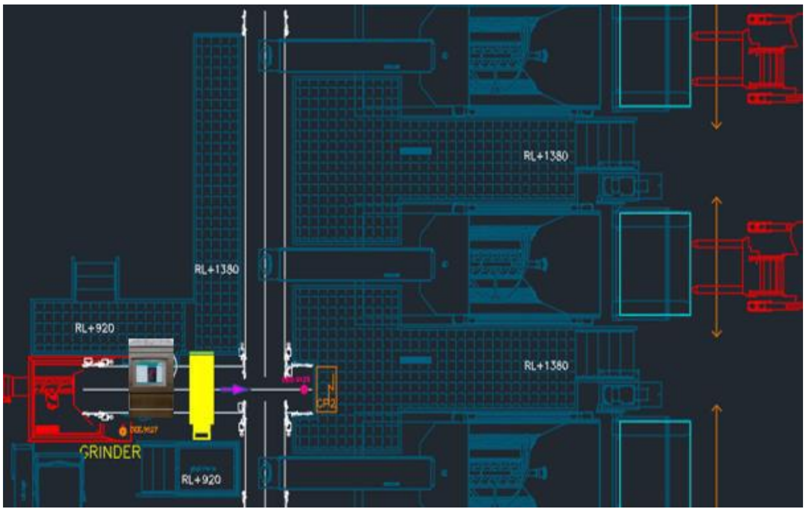

Figure 4: Line layout of the current detection system using Dyna CQ prototype technology.

4.8 Validation Testing Schedule at DMRI laboratory

Retail Ready Operations and DMRI conducted two testing sessions to highlight any limitations or challenges that are specific to the Australian Red Meat Industry.

The tests included Beef and Pork with variable fat to lean meat ratios. The validation tests did not highlight that changing between Pork 3, 4, and 5 Star and Beef 3, 4, and 5 Star would be of issue (fat level variations. The only request, should it prove necessary, may be a selectable recipe between each product type via the user interface to optimise the vision program for each product.

In total 294 tests were completed to understand the success of the proposed solution in relation to the contaminations that Retail Ready Operations are faced with. Refer to appendix 8.2 for the Validation Testing Matrix.

Items tested:

- Dark Blue Bin Liners

- Transparent blue bin liners
- Transparent green bin liners
- Clear Cryovac bags, with black logo text
- Blue rubber gloves and aprons
- Hair Nets, green and red
- Ear Plugs, orange with light blue string

The Foreign Objects have been tested under multiple different scenarios which included the size of the contamination, whether the contamination was embedded in the product or on the surface of the product or if the product was wet. A large number of repetitive tests showed a very high and satisfactory consistency in detection results.

4.9 Review and Recommendations post validation testing to ensure optimal detection of foreign objects and Good Manufacturing Practices.

Retail Ready Operations and DMRI had a final review meeting to understand best operating practices. This included the review of the current contaminations and why the industry should look to move away from transparent poly products for product raw material handling and storage as feasible, as there seems currently not any technological principle available that consistently may detect such items.

Under certain conditions, typically when a transparent bag was smaller than 10mm x 10mm and follows the contour of the meat or conveyor, it proved to be challenging to detect the foreign object.

The following items have been recommended to be reviewed by Retail Ready Operations.

- Very Transparent blue bin liners
- Transparent green bin liners
- Clear Cryovac bags, with black logo

It should be noted that RROA's technical assessment did not see significant risk with transparent green bin liners (even small sized pieces) and therefore not validated. It was therefore recommended to omit green coloured plastic from the test criteria based on RROA's technical experience of test evidence. All Items were detected (refer to Figures 5, 6, & 7).

It is critical that the project reviews and evaluates that the combination of detection method(s) and best management processing practices.

As the selected DynaCQ system is based on imaging analysis, detection of contaminants which visually blend with the product (meat, fat) or the conveyor material will be limited. In this case such limitation is expected with clear, white, and red plastics as these may present an appearance too close to that of the meat. Efforts should be made in avoiding the use of such lesser detectable plastic bags and liners in operations and the supply chain. Conveyor belt selection will also need to be carefully evaluated with the same concept in mind.

Figure 5: Test piece of beef including blue poly and transparent green poly foreign objects

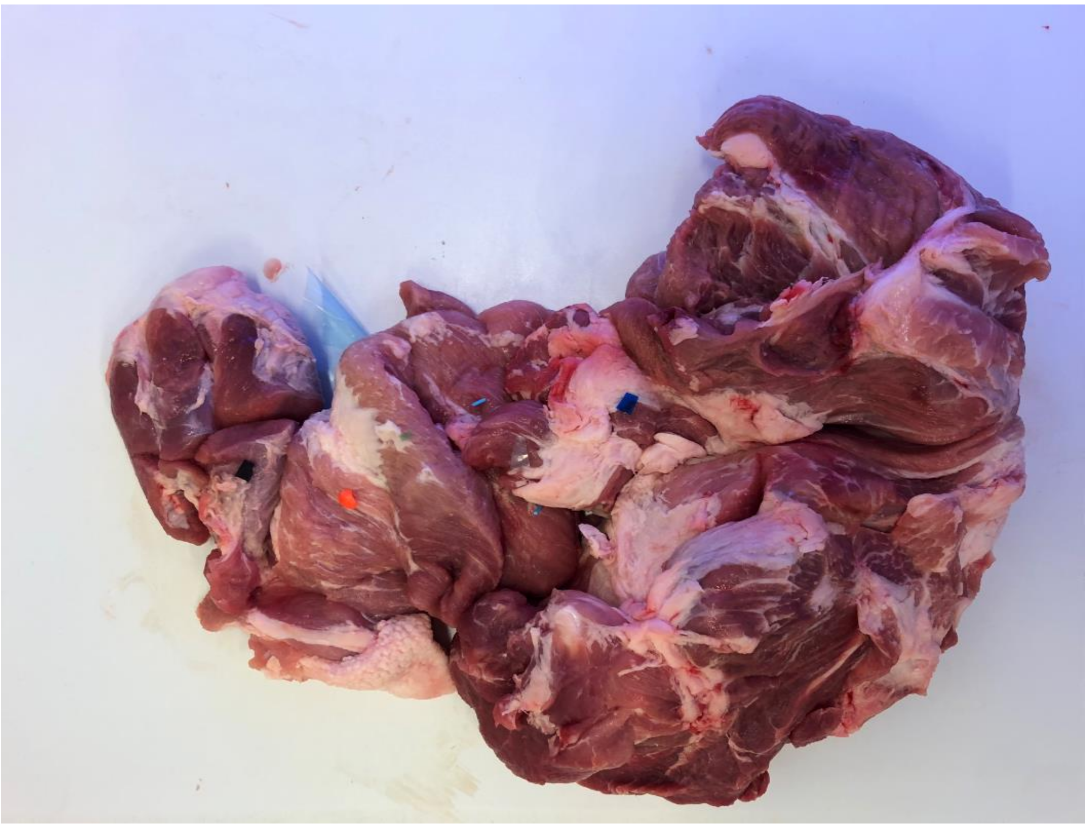

Figure 6: Test piece of beef including transparent blue poly, blue poly foreign objects, ear-plug, and ear-plug string.

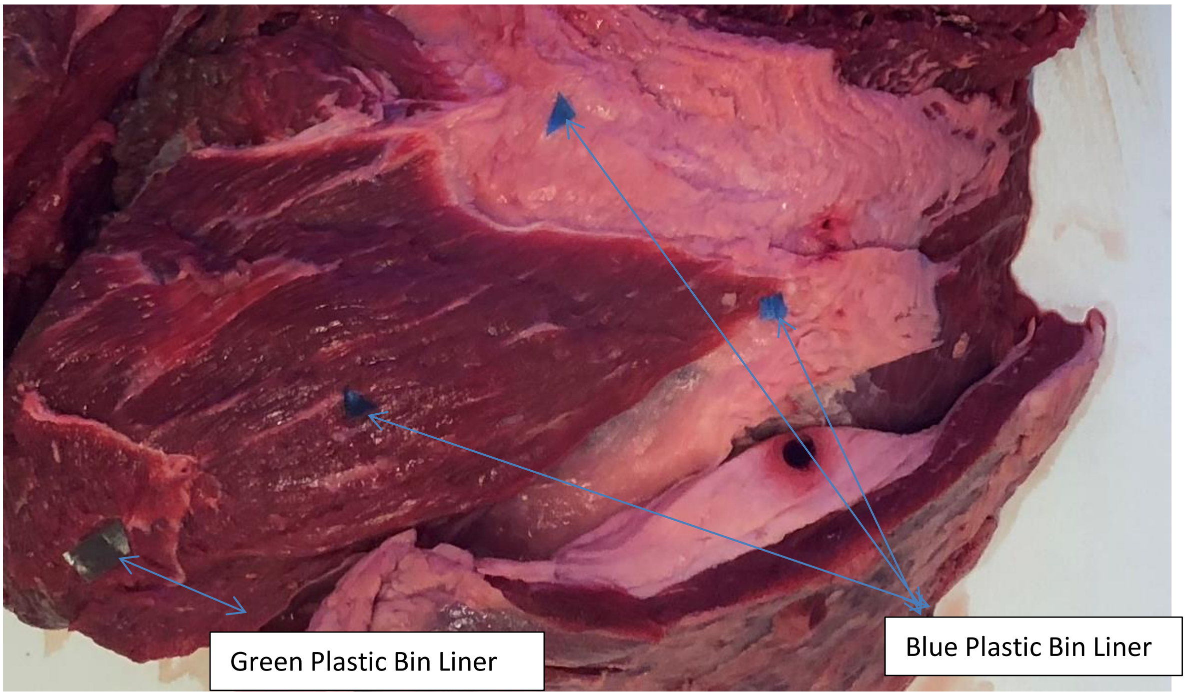

Figure 7: Test piece of beef including blue poly and transparent green poly foreign objects

Zoomed in image of the picture above showcasing how much more the blue poly stands out rather than the transparent green plastic, which however was detected.

4.10 Conveyor Modifications

The existing blue conveyor belt would have limited the detection rate of blue plastic considerably, as these are widely used in production and throughout the supply chain this would be a significant reduction of performance.

DMRI has made recommendations on a specific colour belt with matt appearance to ensure optimal detection rate, their approach in this is to match the colour of the product to limit the span of the non-detectable colour range. In this case an off-white belt matching the fat colour was recommended. Additional to these requirements the belt also needs to be suitable for the 11 degree incline of the conveyor. Smooth slippery belts may cause meat containing purge to slide backwards down the bottom of the conveyor.

Given the specific requirements RROA selected and sourced three different new belt types for the conveyor and had these sent to DMRI labs for testing. Following final selection by DMRI, the optimal belt was retrofitted onto the conveyor.

A new conveyor motor was also installed, allowing for a raise in belt speed which will optimise the success of the vision system by *stretching* the feed of raw material into a thinner stream, reducing the chances of embedded contaminants remaining under the surface and going undetected. An encoder has been integrated with the new motor to provide a speed reference to the vision system allowing it to calculate the optimal image capture rate based on the belt speed and prevent motion blur.

4.11 Installation, Commissioning and Pre-Production Validation at RROA

An installation, commissioning, and Site Acceptance Test (SAT) plan was prepared to provide an outline of the steps and sequence required for installation of the low density contamination vision detection system. The document details the steps required for installation of the system, as well as daily tasks required after installation, e.g. cleaning and start/stop times. Pre-testing and optimisation of the detection software is also included.

RROA received shipment of the DynaCQ vision system in December 2019, it has since been installed on the production line. As planned, the DynaCQ system has been mounted between the metal detector and the first stage grinder (refer to Figure 1).

Figure 8: DynaCQ system installed on conveyor line

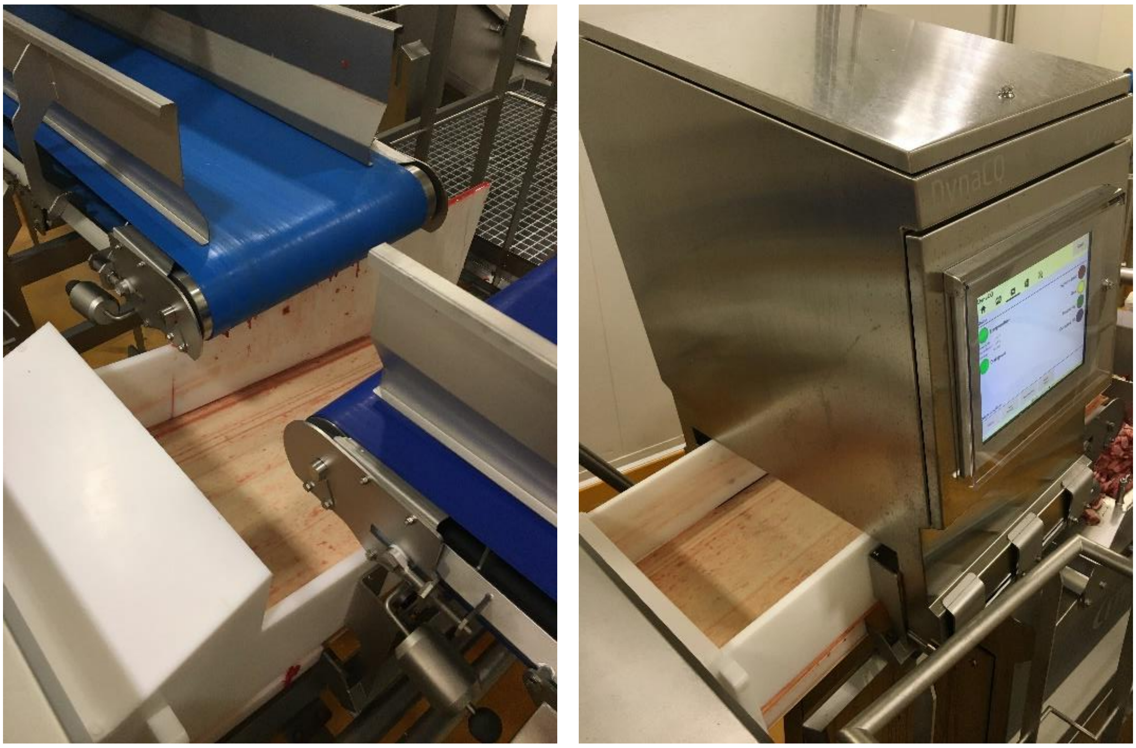

Figure 9: New white conveyor belt

A status light tower has been installed to allow operators to monitor and interpret detection events. It has been mounted in a position providing optimal visibility to the operators on the following codes:

- Red: DynaCQ has a system error and requires an operator to continue.
- Yellow: An operator has stopped DynaCQ.
- Green: DynaCQ is measuring
- Blue: A foreign object has been found. In case of a dialog, this output will stay on until acknowledged by an operator

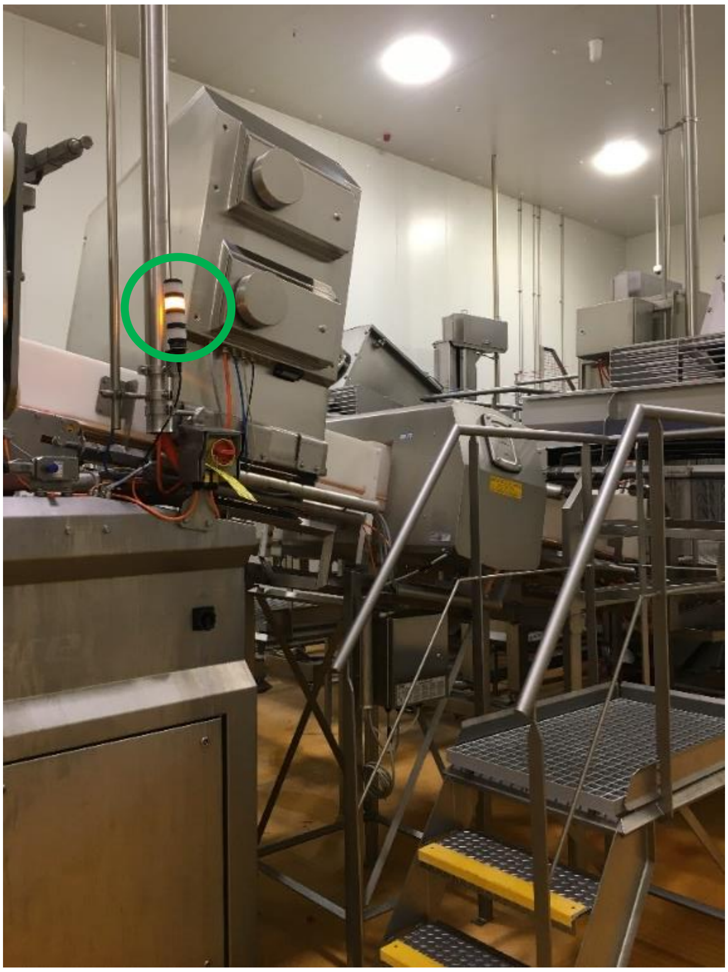

Figure 10: Vision system signal light

4.12 Remote Testing by DMRI

The RROA IT team enabled remote access for DMRI to access the DynaCQ system from Denmark. This access, combined with local assistance with contaminant tests, allowed the DMRI team to start pilot testing the unit in its actual environment prior to on site validation. The following installation tasks were completed remotely:

- Check Ethernet connection and remote access
- Configure virtual belt speed in software using encoder data
- Capture images during production, later used to refine and develop detection algorithm
- Capture images during contaminant testing to refine and develop detection algorithm

Over a four week period the DMRI team monitored performance of the unit by analysing images from the foreign object tests and the detections recorded during normal production. The system was operated in demo mode, allowing it to record detection images without stopping the conveyor.

During this development period a high incidence of blood clots was found to be present on beef, these often appeared as black spots which triggered detection. In order to avoid false detection, it was then decided to increase the detection threshold for black spots to a surface equivalent to 20mm x 20mm. The reasoning for determination of this size was based on the majority of blood clots being smaller than this size and the high risk black contaminant, soaker pads, measuring 140mm x 65mm.

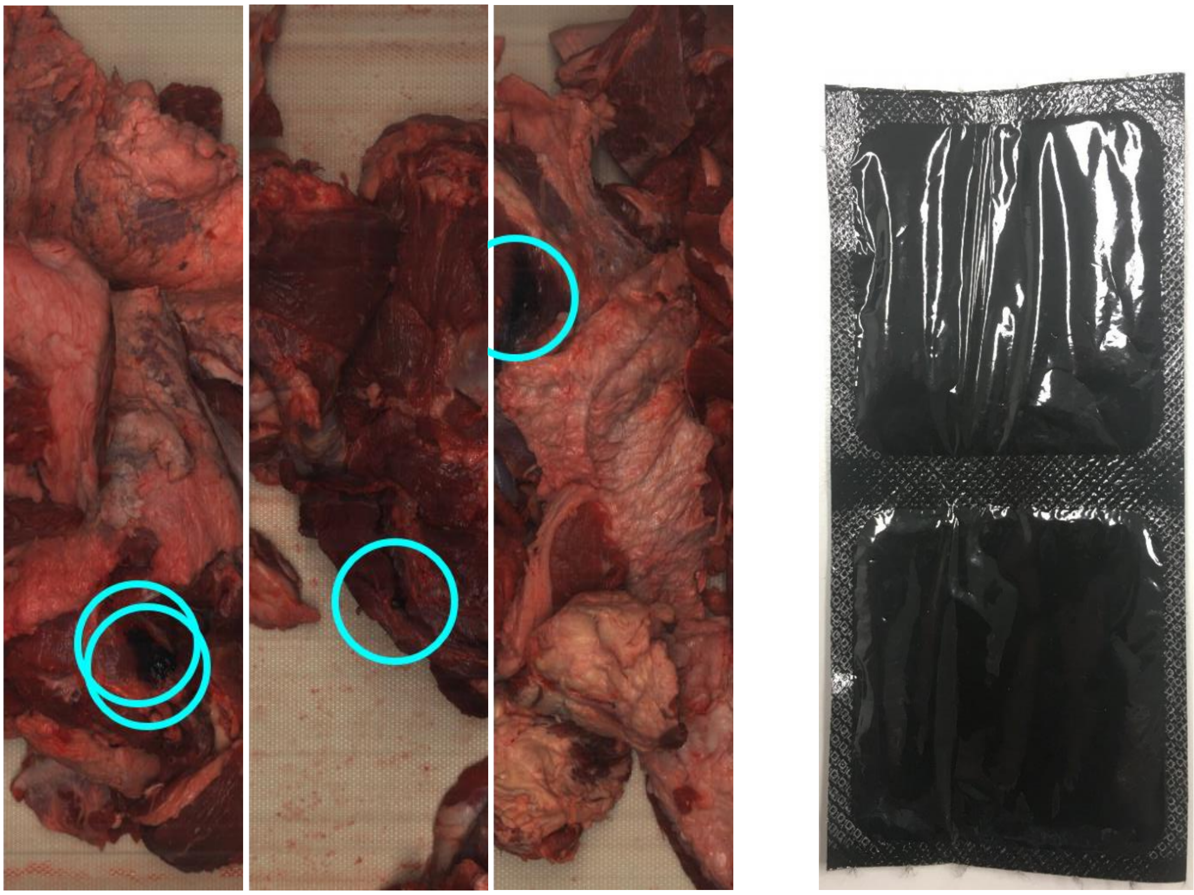

Figure 11: Black blood clot detection images and black soaker pad

4.13 On Site Commissioning and Fine Tuning

The final stages of commissioning were completed with DMRI on site, these included the following actions:

- Verify terminations of the conveyor motor encoder and control cables in the DynaCQ
- Check all comms and I/O over Ethernet, encoder, light tower and PLC
- Configure timing for conveyor start, stop and reverse
- Final testing and tuning of DynaCQ vision detection algorithm

Initial testing of foreign object contaminants indicated some limitations on detection of light-coloured translucent plastics on dark red meat. When wetted or in full contact with the meat (no air gap), the colour of these translucent plastics can become difficult to distinguish from the meat. This was much less the case when applied to pork or fat.

To increase detection rate and meet the SAT criteria, the detection algorithm was updated by the DMRI team. The update resulted in better detection of translucent plastics but also caused a considerable increase in false positive detections. These went from a rate of 5 per day to over 30 per day. The majority of these nuisance trips were due to the silverside or white membrane present on 95CL beef material. As can be seen in figure 12, the white and slightly bluish membranes on beef are visually very similar to plastic film.

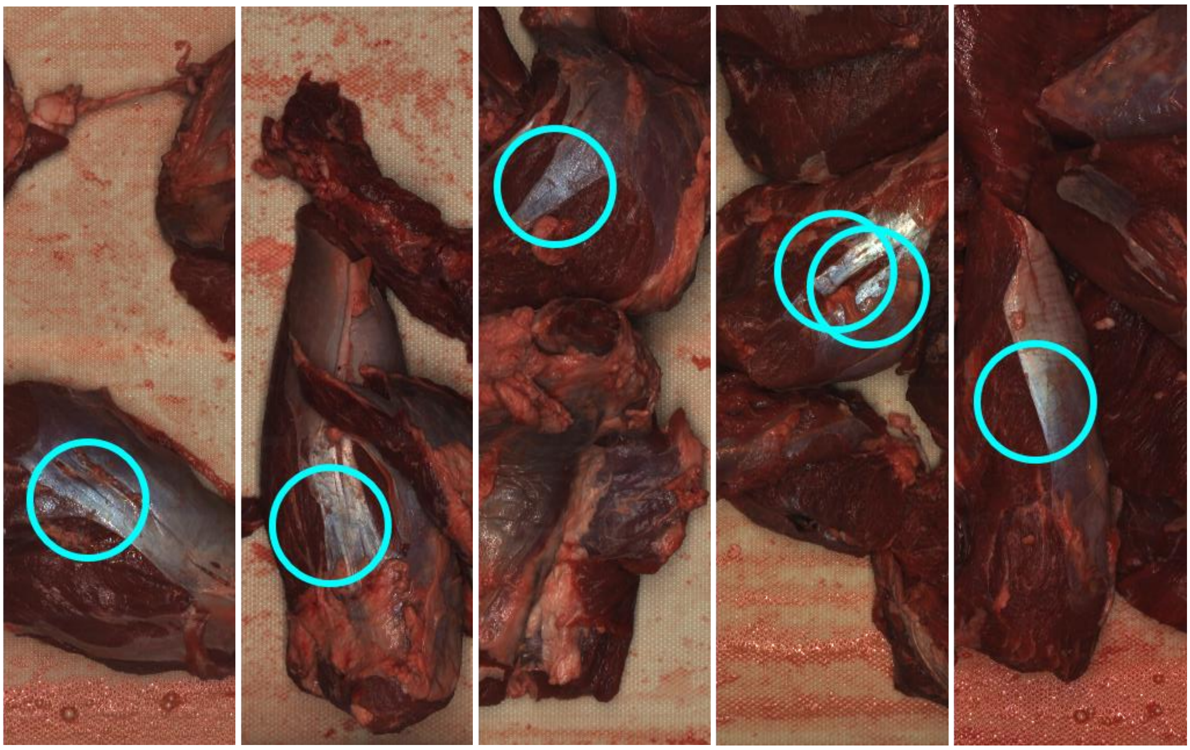

Figure 12: False positive detections on Beef 95CL due to white meat membrane

The false detections highlighted the technology's known limitation on foreign objects exhibiting similar colour to that of the meat. In such cases the detection threshold needed to be adjusted to achieve an acceptable balance between the level of false detections and protection form actual contaminants. It was decided to aim for a detection level resulting in a maximum of 10 false positives per 8 hour shift. Two further algorithm updates were made during the commissioning week to reduce sensitivity to silverside and achieve the target false detection rate whilst maintaining effective detection of sample contaminants.

4.14 Site Acceptance Test (SAT) and Handover

Following the algorithm updates the vision system underwent SAT where beef and pork pieces were spiked with sample contaminants to validate detection levels in different conditions. Refer to the SAT table in appendix 7.3 for test criteria details.

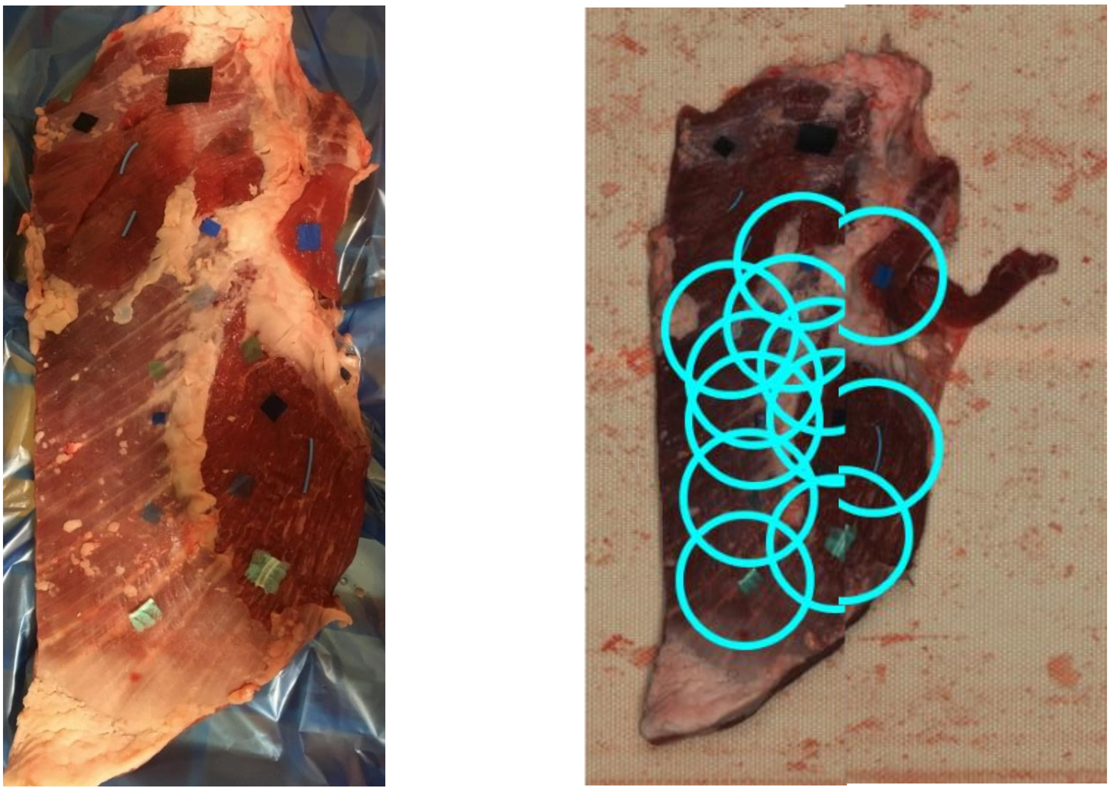

Figure 13: SAT contaminants on beef

Following the SAT process and acceptance, Production Operators, Production Technicians, and Quality Controllers were trained by the DMRI specialist on the system's features and operation. Completion of this project milestone enabled the project team to handover the system to operations.

4.15 Development and Implementation of Periodic Validation Program

The RROA Quality Assurance department has been working with the project team in developing a periodic validation program for this system. Essentially, a simplified version of the SAT will be performed by Quality Controllers on a monthly basis to validate the detection performance and functionality of the system. This will ensure the system continues to provide the expected level of detection and document its performance.

5 Discussion

5.1 Performance Evaluation

Despite some inherent limitations of the technology, the system's performance meets the application requirements and is in line with expectations. When considering potential plastic entrapment contamination scenarios, the likelihood is for pieces much larger than 5cm^2 to be present on the surface. Even if some parts of a contaminant may be hidden, it is unlikely that all of the piece or pieces go undetected because they are under the meat or not showing enough surface area. Real contamination events will likely present themselves in a similar way to those shown in figure 14, providing good exposure conditions for detection by the vision system.

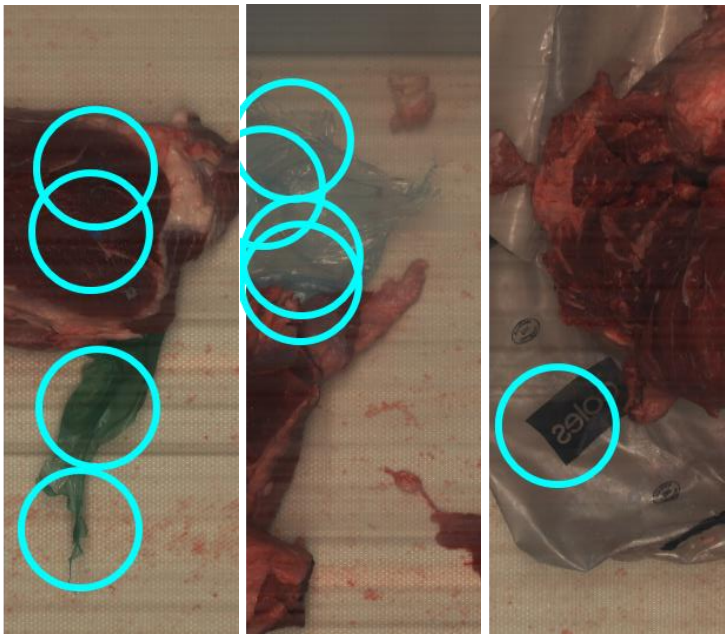

Figure 14: Simulated contamination scenarios

5.2 Production Experience

Following commissioning of the unit, new procedures have been put in place for cleaning and production. Machine interlocks have been instated which prevent the production conveyor to run without the vision system being active, this ensures that all raw material is inspected before it reaches the pre-grind operation.

Having been involved in the commissioning trials has allowed operators to better understand the systems functionalities and witness its effectiveness. All team members involved have welcomed the change and appreciate the value the system brings to their production operations by ensuring food safety of the finished product.

5.3 False Positives

Monitoring of the systems performance in terms of false positives has also continued in the weeks following handover. Despite optimisations to the algorithm during the commissioning week, the incidence rate of false positives occasionally exceeds the daily objective of 10 per 8 hour shift. Similarly to what was observed during commissioning, 80% of these false positives are due to the silverside membrane which, due to its white or bluish light reflection, is visually very similar to plastic film. Refer to figure 12 in section 4.13.

Collaboration between DMRI and RROA is continuing; the DMRI team will be working on implementation of texture analysis into the inspection algorithm as a new way of differentiating between the organic membrane and plastic film. If successful this will allow a reduction in the occurrence of false positives and the associated disruption to operations without reducing the sensitivity threshold to light coloured plastic film.

5.4 Fit for Purpose Evaluation

In addition to detection performance, the unit has been evaluated for its general design, construction, and operability. The unit meets the Food safe equipment design requirements and so far, the DynaCQ system is also proving to withstand very well to daily washdown and the wet production environment.

From a user perspective, the system is simple to use and requires minimal operator intervention to operate. The user interface is a large, high quality, touch screen which provides easy access to a simple and intuitive menu.

With no moving parts, the system has no regular maintenance requirements other than the daily cleaning of the lens. Network connectivity features provide the possibility of remote access and management of the data for archiving of quality records.

5.5 Cost Benefit Analysis

The risk of low desnity polymer or other contaminants making their way through the raw material infeed process poses a serious risk to food safety and can cause considerable brand damage and financial losses.

The following cost benefit analysis considers the avoidance of minor contamination incidents, where detection is made early and major financial and brand damage avoided. Such incidents still involve considerable losses of materials and productivity for the producers.

The cost of material and labour losses from a single incidence of an early detected contamination in mince is estimated at $35,000.

These costs are based on early detection with no contamination reaching or requiring disposal of finished (retail/packaged) product. The costs associated with later detection would increase exponentially as the contaminated product travels further downstream through production and the supply chain, requiring disposal of finished product and recall from transport services, distribution centres, or retail stores.

For a standard installation on an existing conveyor system not requiring any major modifications, the costs associated with the acquisition and installation of the vision detection unit can be summarised as follows:

Acquisition and Installation Costs	
DynaCQ Visions System	$220,000

Mechanical & Electrical Installation	$35,000
Engineering & Project Management	$20,000
Total	**$275,000**

The total cost of $275,000 for the equipment would be outweighed by avoidance of only 8 of the least damaging early detected incidents.

5.6 Internal Business Case

Further to the financial justification based on the conservative hypothetical incidents outlined in the cost benefit analysis, justification for implementation of this solution is based on the fact that there is a known and substantiated risk of contamination into mince from low density foreign objects.

As a first justification, commitment to ensuring consumers are provided with quality and safe products is strong support to any measure which can be taken to reduce risks to food safety.

Justification can also be made from a financial risk perspective as the cost impact of brand damage that would be caused by a single contamination reaching stores or consumers far outweighs the implementation costs.

6 Conclusions/recommendations

6.1 Conclusion

RROA is extremely satisfied with the trialled systems performance. All department managers and team members have appreciated the significant reduction in the risk of contamination to the mince lines.

The system has also been well received by operators who, despite the introduction of the occasional false detections interrupting their production process, are pleased to know the system is helping them reduce the risk of contamination.

The SAT and fine tuning of the algorithm has provided a better understanding of the detection threshold levels and trade off with the number of false positives. This clearer definition of the systems strengths and limitations confirms the need for the elimination of clear and light coloured or translucent plastics from the network. A business case is being prepared for this initiative which will require changes for many supply chain partners.

6.2 Recommendations

Based on the positive trial results and experience, cost benefit evaluation and internal business case, it is recommenced that RROA adopt this solution. The other main recommendations include:

- Continue use and monitoring of the system with periodic validation
- Eliminate the use of clear plastic bags from the supply chain
- Consider application of the solution to other production areas such as poultry processing

Parallel to the in-depth knowledge being acquired on the DynaCQ system, it is recommended that RROA continue to gather information on other potential detection technologies. These alternatives, such as the recently presented X-ray imaging solutions by Rapiscan, remain of high interest and could be evaluated as part of this project, the innovations programme, or be put forth as a new project application. It is critical that the project consider the combination of available detection method(s) to develop the best management practices.

7 Key messages

7.1 Success in achieving the Milestones

The key deliverables for this project milestone as set out in Section 3, Methodology, have been met by completion of:

- Validation of the Dyna CQ system to ensure it covers all requirements of Retail Ready Operations.
- Planning and installation of the DynaCQ system.
- Commissioning and pre-production validation.
- Optimisation of the vision system detection algorithm.
- Development and implementation of Periodic Validation Program to ensure the integrity of the DynaCQ system over an extended period.
- Ensure all recommendations are captured to further enhance the chances of foreign object detection and Good Manufacturing Practices.

Based on the completed elements and the progress made on the deliverables, this project is considered to have achieved full completion.

7.2 Recommendations to wider Industry

The positive outcome and experience with the DynaCQ system at RROA should be a strong case for adoption into similar applications within the wider Australian red meat industry.

All producers and brand owners will benefit from a reduction in the risk of contamination incidents in the Australian red meat offer to consumers.

The technology is simple yet effective and reliable. Its non-intrusive nature and small footprint should make it relatively easy to adapt to most existing production facilities.

8 Appendix

8.1 DynaCQ System

Plastic detection

Coarse ground products

DynaCQ provides on-line inspection of coarse ground fresh or frozen products to ensure they are free from unwanted contamination like plastic or other objects

CONCERNED ABOUT FOREIGN OBJECTS?

Low density materials like plastic and paper are used extensively in the food production. However, they cannot be found by the conventional technologies for foreign body detection, i.e. x-ray and metal detectors that target high-density materials and metals. Even small fragments of plastic or paper can cause considerable incon-venience and can result in a significant recall cost for the supplier.

DynaCQ analyses image data captured on-the-fly and detects even minuscule unwanted objects on the product surface (down to 1.5x1.5 mm). With the DynaCQ quality inspection, you can prevent contami-nated products from reaching the consumer, and you can quickly take corrective actions to reduce product waste. Stored images can be used for documentation and root cause analysis.

DynaCQ marks unwanted objects with a halo.

DYNACQ OFFERS

- Automatic surface inspection for foreign objects (FO)
- Including low density and non-metallic objects
- Minimized recall cost and product waste
- Documentation of your products by stored images
- Avoiding operator fatigue by automatic inspection

DynaCQ is designed to be installed on top of existing con-veyors and is compatible with conveyor speeds in the meat industry. The final DynaCQ product quality check can be combined with both manual and automatic removal, i.e. with line-stop, push-out or robotic removal.

DYNACQ DETAILS

- Dimensions, cm: H120xW60xD82
- Field of view, cm: max 51, (E2 box)
- Power/use: 230V AC, 300W
- IP66/69 Cabinet
- Industry wash down air locks
- EMC, CE, EU 852/853/1935 (2004)
- Minimum detectable FO size: >= 1.5 mm by 1.5 mm (product and FO specific)
- Response time: exit unit (product, FO & belt speed specific)

The standard software is calibrated to check the product stream of the coarse ground products for different colored plastic fragments or other contamination, but the soft-ware can be adapted for numerous other quality checks, replacing visual inspection:

- Detect foreign objects in meat cuts, steaks, dices, pulled and processed ground product placed on a conveyor belt, in a box or tray
- Monitor give-away in deboning processes, such as meat on bones and meat on fat
- Automatic product identification for production follow-up and product destination
- Quality control of product styling of food products in retail packs e.g. from manually or automatically filled retail packs
- Quality control of composite food products in which number, positioning and quality of the individual compos-ites are critical

8.2 Validation Testing Matrix

Low Density Detection Validation Matrix

Product Blend/Reciepe	Foreign Object	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15	Test 16	Test 17	Test 18	Test 19	Test 20	Test 21	Test 22	Comments	Recommendations
Beef Mince	Dark Blue Poly Bag	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass		
Beef Mince	Transperent Blue Poly Bag	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Review	Review	Review	Review	Review	Review	Blue Transperent bags are challenging to detect if the bag is following the meat profile. The Bag appears to look very similar to the meat and due to this fact we can not gurantee a successful detection on all occasions	Review the current bag type and look for a less transperent bag type
Beef Mince	Black Coles Logo from Clear Poly Bag	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Review	Review	Review	Review	Review	Review	Clear Transperent bags with the black coles logos are challenging to detect if the bag is following the meat profile. The Bag appears to look very similar to the meat. We require a minimum amount of the black coles logo to be present to allow detection. Due to it being black makes it challenging as a shadow is essentially projected as black so we need to prevent false positive tests.	Review the current bag type and look for a less transperent bag type or at a minimum look at changing the Coles logo from black to green or blue. The black logo can be mistaken for a shadow which leads to false positive trips
Beef Mince	Transperent Green Poly Bag	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Review	Review	Review	Review	Review	Review	GreenTransperent bags are challenging to detect if the bag is following the meat profile. The Bag appears to look very similar to the meat and due to this fact we can not gurantee a successful detection on all occasions	Review the current bag type and look for a less transperent bag type
Pork Mince	Dark Blue Poly Bag	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass		
Pork Mince	Transperent Blue Poly Bag	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Review	Review	Review	Review	Review	Review	Blue Transperent bags are challenging to detect if the bag is following the meat profile. The Bag appears to look very similar to the meat and due to this fact we can not gurantee a successful detection on all occasions	Review the current bag type and look for a less transperent bag type
Pork Mince	Black Coles Logo from Clear Poly Bag	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Review	Review	Review	Review	Review	Review	Clear Transperent bags with the black coles logos are challenging to detect if the bag is following the meat profile. The Bag appears to look very similar to the meat. We require a minimum amount of the black coles logo to be present to allow detection. Due to it being black makes it challenging as a shadow is essentially projected as black so we need to prevent false positive tests.	Review the current bag type and look for a less transperent bag type or at a minimum look at changing the Coles logo from black to green or blue. The black logo can be mistaken for a shadow which leads to false positive trips
Pork Mince	Transperent Green Poly Bag	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Review	Review	Review	Review	Review	Review	GreenTransperent bags are challenging to detect if the bag is following the meat profile. The Bag appears to look very similar to the meat and due to this fact we can not gurantee a successful detection on all occasions	Review the current bag type and look for a less transperent bag type
Beef Mince	Rubber Gloves	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass		
Beef Mince	Aprons	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass		
Beef Mince	Long Rubber Gloves	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass		
Beef Mince	Hard Plastics	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass		
Beef Mince	Ear Plugs	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	When the ear plugs are soaked in meat juice we do have trouble detecting due to the ear plug can be mistaken for Red Meat not the orange colour	
Beef Mince	Hair Net	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Review	Review	Review	Review	Review	Review	When the hair net are soaked in meat juice we do have trouble detecting due to the hairnet can be mistaken for Red Meat not the oactual hair net. Also at a lower area detection test due to the make up of the hair net the minimum pixel threshold is not made.	

Testing Enviroment Condtition 1	Conveyor speed is to be configured to the same as Coles RROA
Testing Enviroment Condtition 2	Product Spread to be similar to current production
Testing Enviroment Condtition 3	Lighting is to be measured at DMRI to compare with the lighting at RROA
Testing Enviroment Condtition 4	
Testing Enviroment Condtition 5	
Testing Enviroment Condtition 6	
Testing Enviroment Condtition 7	

Test 1	Place the contamination on the top surface of the meat - 100mm x 100mm piece of contamination
Test 2	Place the contamination on the conveyor and place meat on top of the - 100mm x 100mm piece of contamination
Test 3	Partially Embed a - 100mm x 100mm piece of contamination
Test 4	Embed 80% of the - 100mm x 100mm piece of contamination
Test 5	Embed 90% with the 10% being perpindicular to the conveyor - 100mm x 100mm piece of contamination
Test 6	Wet The Plastic and Meat - Embed 80% of the - 100mm x 100mm piece of contamination
Test 7	Place the contamination on the top surface of the meat - 25mm x 25mm piece of contamination
Test 8	Place the contamination on the conveyor and place meat on top of the - 25mm x 25mm piece of contamination
Test 9	Partially Embed a - 25mm x 25mm piece of contamination
Test 10	Embed 80% of the - 25mm x 25mm piece of contamination
Test 11	Embed 90% with the 25% being perpindicular to the conveyor - 25mm x 25mm piece of contamination
Test 12	Wet The Plastic and Meat - Embed 80% of the - 25mm x 25mm piece of contamination
Test 13	Place the contamination on the top surface of the meat - 10mm x 10mm piece of contamination
Test 14	Place the contamination on the conveyor and place meat on top of the - 10mm x 10mm piece of contamination
Test 15	Partially Embed a - 10mm x 10mm piece of contamination
Test 16	Embed 80% of the - 10mm x 10mm piece of contamination
Test 17	Embed 90% with the 10% being perpindicular to the conveyor - 10mm x 10mm piece of contamination
Test 18	Wet The Plastic and Meat - Embed 80% of the - 10mm x 10mm piece of contamination
Test 19	Place the contamination on the top surface of the meat - 1.5mm x 1.5mm piece of contamination
Test 20	Place the contamination on the conveyor and place meat on top of the - 1.5mm x 1.5mm piece of contamination
Test 21	Partially Embed a - 1.5mm x 1.5mm piece of contamination
Test 22	Wet The Plastic and Meat -80% of the - 1.5mm x 1.5mm piece of contamination

8.3 Updated Validation Testing Matrix

Low Density Foreign Object Detection in Mince Standardisation

DynaCQ Validation

Low Density Foreign Object Detection Validation Matrix

Product	Foreign Object	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15	Test 16	Comments
Beef	Dark Blue Poly Bag	P	P	P	P	Dependant on angle	P				P	Dependant on angle	P					May fail if wet and over very dark meat; black appearance
Beef	Transparent Blue Poly Bag	P*	F	P	P		F				P		P					* Fails on dark meat if wet/ tight over surface
Beef	Black Coles Logo from Clear Poly Bag	P	P*	P*	F		F				P		P					* Requires logo to be showing sufficient printed surface, blue logo better than black
Beef	Transparent Green Poly Bag	P	P	P	P		P				P		P					May fail if wet and over very dark meat; black appearance
Pork	Dark Blue Poly Bag	P	P	P	P		P				P		P					
Pork	Transparent Blue Poly Bag	P	F	P	P		F				P		P					
Pork	Black Coles Logo from Clear Poly Bag	P	P	P	F		P				P		P					Requires logo to be showing sufficient printed surface, blue logo better than black
Pork	Transparent Green Poly Bag	P	P	P	P		P				P		P					
Beef	Blue Rubber Glove	P	P	P	P		P				P		P					
Beef	Apron/ Sleeve	P	P	P	P		P				P		P					
Beef	Ear Plugs	P	P	P	P		P				P		P					
Beef	Green Hair Net	P	P	P	P		F				P		F					Wet or single layer hair net not detectable, ok when folded
Beef	Black soaker pad	P	P		P		P											Due to false positives on blood clots, treshold is set at 20mm x 20mm

	Test Description
Test 1	Place FO on top of the meat - 40mm x 40mm piece
Test 2	Place FO on conveyor and place meat on top - 40mm x 40mm piece with at least 10mm x 10mm showing
Test 3	Place FO on top of the meat - 10mm x 10mm piece
Test 4	Place FO on top of the meat - 20mm x 20mm piece
Test 5	Place FO perpendicular to the top of the meat - 10mm x 10mm piece
Test 6	Place wet FO on top of the meat - 20mm x 20mm piece
Test 7	~~Place the contamination on the top surface of the meat - 25mm x 25mm piece of contamination~~
Test 8	~~Place the contamination on the conveyor and place meat on top of the - 25mm x 25mm piece of contamination~~
Test 9	~~Partially Embed a - 25mm x 25mm piece of contamination~~
Test 10	Place FO on top of the meat - 5mm x 5mm piece
Test 11	Place FO perpendicular to the top of the meat - 3mm x 3mm piece
Test 12	Place wet FO on top of the meat - 5mm x 5mm piece
Test 13	~~Place the contamination on the top surface of the meat - 10mm x 10mm piece of contamination~~
Test 14	~~Place the contamination on the conveyor and place meat on top of the - 10mm x 10mm piece of contamination~~
Test 15	~~Partially Embed a - 10mm x 10mm piece of contamination~~
Test 16	Place FO on top of the meat - 2mm x 2mm piece

P Pass; detection successful

F Fail; FO not detected

Date:

Testing Performed by:

Lau Nielsen

Francois Tabbakh