final report

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Automated beef evisceration – Stage 1

Feasibility study

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Executive Summary

Currently the evisceration process for beef is a manual task offering tremendous OH&S risks. The evisceration task requires complex and heavy manual handling, separation and manipulation of the beef carcase, viscera and organs in an unstructured environment with variability in carcases. Together with the unpleasant nature of the task these pose the majority of the challenges for any slaughter person performing the task.

Research shows that the manual process is difficult and labour intensive and that automation is highly desirable. This project aims to evaluate the beef evisceration to determine the best path towards development of an automated solution for beef evisceration.

For this report three plants were evaluated and the current manual process of Beef Evisceration was reviewed. Following this evaluation and review concepts were developed for the automation of the Evisceration process. These concepts incorporate the use of standard industrial robotic and vision systems along with the development of a robotic evisceration tool and tray/support mechanism.

A process for development towards a commercial system has been detailed and a time frame for this to occur has been included.

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1 Background

1.1 Industry Consultation

MAR have consulted with and visited many processors where the evisceration process has been observed with the view of future automation possibilities. In discussion, all consulted consider this process important and urgent to automate as the task is highly arduous, ergonomically unfriendly and generally unpleasant. An automated solution at the right price would also bring savings, consistency in throughput and importantly a reduction in associated OH&S issues.

The level of interest to see automation on a fast track development is high with one major aspect being the difficulties recruiting and retaining staff engaged in this area of processing.

1.2 How has the project “come about”?

Industry drivers to address known OH&S issues plus progression of a similar project to develop an automated solution for small stock evisceration have highlighted the need and encouraged MAR to address the need and challenge the development of an automated beef evisceration solution.

1.3 What Currently Happens and Why Does it Need Changing?

Currently the manual process is difficult and labour intensive with no automation possibilities as the task requires complex handling, separation and manipulation of carcase, viscera and organs in an unstructured environment with variability in carcases that pose challenges for automation.

An automated solution would address key production efficiencies and provide major benefits with positive impacts on critical industry OH&S issues.

The key drivers are:

- Improvements in OH&S through elimination of current manual labour intensive tasks
- Reduction in labour and recruiting cost
- Improve staff retention
- Reduce training of skilled labour
- Reduced contamination
- Improved consistency of operation (Rework/Yield)
- Improved sanitisation procedures
- Another step towards a fully integrated line

1.4 What alternatives have been investigated or are available?

No automated solution for beef evisceration is currently available. This project will identify alternative methods for the path to automation for consideration prior to executing full development.

1.5 What happens in other industries?

Studies performed by MAR for small stock evisceration have identified a new approach which allows automation to be realised and developed meeting the needs of the end-users. MAR have completed automated Evisceration Tooling trials fully supported by MLA and AMPC. The pork industry uses a number of automated evisceration methods in production, however this technology as it was for small stock is not directly transferable to beef processing.

1.6 Experimentation/Investigation work to date

MAR have visited numerous processing sites within Australia to review beef evisceration automation possibilities with the support of MLA. We have consulted with and visited many processors where the evisceration process has been observed with the view of future automation possibilities however no physical experimental work has been completed for beef evisceration.

Manual and automated trials for a small stock evisceration tools adapted to a robot system were completed in June 2010.

1.7 Estimated cost before and after on the impact to the Processor

The cost benefit will be in terms of labour reduction and suppression of OH&S claims related with the evisceration tasks. The latter will be variable and specific to each site. The former can be easily quantified, depending on each plant labour cost, but never less than $220,000 per shift per year.
A final commercial automated evisceration system would aim to have an estimated payback within 2 years.

This approach aims to save 1-2 units of labour per shift. This will reduce the operating costs significantly. Operating cost would be equivalent or less than the upkeep cost of labour in such positions in terms of overheads related to employment, insurance and other such cost attributed to the labour to be saved.

1.8 Footprint required within plant for installation

Any solution to be developed would aim to satisfy the following:

- adapt to existing beef slaughter floors
- flexible design enabling customisation within variant process floor layouts
- scalable design to compliment line speed requirements
- use of existing offal conveyor systems

2 Project Objectives

MAR will complete the following during this project:

- Site evaluations to determine site restrictions and requirements of a full system
- Engage and work with beef industry processing experts (i.e. John Hughes/Harry Schultz)
- Complete process evaluations to determine:
    - Suitable tooling development requirements
    - Offal separation requirements
    - Procedures should contamination or disease be recognised during automated process
- Engage and consult with industry automation partners
- Develop concept only for prototype tooling to replace manual operations
- Provide and document a development path towards automation
- Report and document findings

3 Methodology

The following milestones outline the approach that will be undertaken to achieve the required project outcomes:

Milestone 1 - Plant evaluations
Plant evaluations (3 processing plants) to determine site restrictions and requirements of a fully automated beef evisceration system. To be completed by MAR with industry expert consultation.

Milestone 2 - Process Evaluations
Process evaluations to determine requirements for suitable tooling development and offal separation. This includes consultation with industry expert to determine scope of process variants concentrating on methodology to ensure requirements are met. To define a basic functional specification for the process.

Milestone 3 - System & Tooling Design Concepts
Develop concepts including consultation with MAR technology partners for new Beef EV tool or tools and overall system design to suit plant variant options.

Milestone 4 - Report Documentation
Report and document findings to provide a development path towards automation outlining in detail a proposal for next development stages.

4 Results and Discussion

4.1 Plant Evaluations

4.1.1 Visits to Plants

Three plants were visited during the course of this project, these plants being:

- Teys Brothers Beenleigh
- John Dee Warwick
- Hardwick's Kyneton

The process of evisceration of beef carcases has been observed in each of these three plants and the findings highlight that while the outcome of the process is the same for all three plants there are slight differences in the way that this outcome is achieved. These are due to the available space in the plant and the line layout. Each plant seems to be faced with similar issues surrounding production, unnecessary stoppages, veterinary issues in carcase, offal, viscera and carcase inspection, equipment cleaning procedures, OH&S and manning levels. General feed back from the plants with regard to the introduction of automation to the evisceration process is that it is seen as a positive thing. The observations made at each plant are detailed below and shown in the attached videos.

Teys Brothers Beenleigh (Video: Teys Bros Beef Evisceration)

At Teys Brothers three operators performed the evisceration process on a moving evisceration table. The carcase is presented with the brisket already cut, the belly is opened and the viscera and organs are all removed by the one operator and dropped onto the moving evisceration table the whole process taking between 50 and 60 sec . Once the evisceration process is complete the operator walks off the evisceration table and through an apron and boot wash then sterilises his knives before moving to the next carcase. The speed of the line was approximately 120 carcases per hour.

John Dee Warwick (Video: John Dee Beef Evisceration)

As with Teys Brothers the evisceration process at John Dee is performed on a moving table. The process was being performed by two operators at the time of the site visit. The briskets are cut prior to arriving at the evisceration table, the belly is opened and the viscera and organs all dropped onto the evisceration table by one operator. Having completed the evisceration of a carcase the operators followed the same cleaning and sterilisation process as seen at Teys Brothers. Again the process took about 55 seconds to complete.

Hardwick's Kyneton (Video: Hardwicks Beef Evisceration)

Hardwick's eviscerate using a different process to the other two sites. Instead of a moving table they have a trough that the viscera drops into and the activities performed by the operators are different. The carcase arrives at the evisceration area with the brisket uncut. One operator cuts the brisket, opens the belly and drops the viscera into the trough below. The carcase then moves onto the next operator who removes the organs and places them on tables in the evisceration area.

In all three plants visited, with some reorganisation of the layout, sufficient space is available for the installation of equipment, however attention would need t be paid to the detailed design allowing manual backup if needed.

4.1.2 Plant Discussions, Automation requirements and Feedback

During discussions plant managers indicated that automation of the beef evisceration process is an attractive proposition due to the OH&S issues associated with the highly arduous, ergonomically unfriendly and generally unpleasant task of eviscerating a carcase. General feedback regarding what the correct solution should consist of was:

- That the automation be simple and easy to operate.
- The equipment be compact requiring minimum change to the line.
- That the automation eliminates as many steps as possible whilst meeting with hygiene and between cycle sanitisation.
- That a high degree of reliability be achieved and allow the plants to maintain their current throughput in terms of carcases per hour. The line is not to stop for the robots or any automated device.
- That the automatic process deals with the carcase variability as well as the variability in the presentation of carcases.

A positive feel was experienced about automation of the evisceration process from a floor level through to management. As stated previously video footage was acquired at each of the plants and this footage has been used to examine the process and derive possible areas where the task of evisceration can be automated.

4.2 Process Evaluation

As has been established from the visits to plants the process of beef evisceration is currently a totally manual operation that requires a significant degree of handling, judgement and manipulation of the carcase, viscera, and various organs and offal. It has been observed that this manual process involves significant lifting and moving operations. This project aims to assess the possibilities for automation of this process and to draw together the specification and plans for design and build of such a system.

4.2.1 Preparation of Carcase for Evisceration

The preparation of the carcases for evisceration starts early on in the line. The tasks that are relevant to this preparation are detailed below. Other processes such as hide, head and hock removal also take place prior to evisceration, however the tasks detailed below are the main ones required to allow evisceration to take place without contaminating the carcase.

1) Rodding and sealing the weasand (oesophagus)

The purpose of rodding and sealing the weasand is to separate it from its natural attachments to the windpipe and prevent the leakage of ingesta to prevent contamination of edible product. The process involves making an incision in the neck and locating the weasand and freeing this to enable the placement of a rod over the weasand. The rod is then pushed as far as possible along the weasand towards the gut freeing the weasand along its length from the connecting tissues. The rod is then withdrawn and a clip applied to the weasand, the clip is then pushed along the length of the weasand to the gut sealing the weasand as close to the gut as possible. Images of the rod and clip are shown below and video of the process (Video: Rodding and Sealing the Weasand) is attached.

Fig.1 Rodding tool and Weasand Clip

2) Ringing and Bagging the Bung

The process of ringing and bagging the bung is performed to seal the anus and urethra so as to prevent the spillage of faecal matter and eliminate the risk of contamination of edible product. This process is performed manually or using a semi automated device. Manually the process is as follows:

- An elastic band is placed onto the wrist, or expanded using a dedicated tool (see image below)
- A bung bag is inverted over part of the Operator's forearm and hand.
- A cut is made between the tail and the anus (vulva in females), care must be taken to avoid puncturing the bung.
- Once the bung is free of its natural attachments it is pulled upwards, the bag is pulled from the forearm and over the freed bung and urinary tract and sealed using the rubber band.
- The bagged bung is pushed down into the anal channel allowing it to be pulled out during the evisceration process.

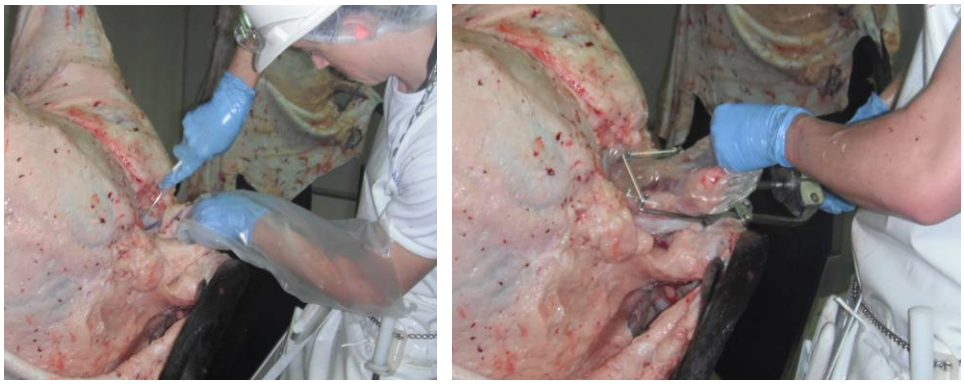

Fig.2 Manual bagging of the bung

The semi automated device follows the same process and is shown in the image below.

Fig. 3 Semi automated bagging of the bung

3) Brisket Cutting

As mentioned previously, depending on the available space and line layout, the brisket may be cut prior to arriving at the evisceration station or performed by the operator eviscerating the carcase. A mechanical reciprocating saw which has a round knob on the end of the blade is used to perform the cut. The blade of the brisket saw is inserted at the naval end of the brisket (sternum) next to the white fan shaped cartilage (xiphoid). Care is taken to avoid cutting through the xiphoid cartilage, located at the top/naval end of the brisket, keeping it whole to protect the eviscerator's arms when opening the cavity and avoids the paunch and small intestines catching on an exposed bone. The brisket bone is then split from the naval end to the point end, to line up with cut made for the thoracic stick. Care is taken not to insert the saw too deeply so as to avoid it cutting the paunch or the runners.

4.2.2 Current Evisceration Process

Following the three tasks above the carcase is in a state where it can be eviscerated with the least potential for contamination. The evisceration process can be broken down into two parts:

1) Removal of the 'White Offal' which consists of the Bung, the paunch, Weasand and Intestines

2) Removal of the Pluck consisting of the heart, lungs and red offal.

4.2.2.1 White Offal Removal

The process begins with the opening of the belly by cutting through the abdomen along the medial line. The cut extends from aitchbone to the xiphoid cartilage which is attached to the brisket. This cut is made with a sterilised knife in one continuous stroke with the handle inside the abdomen and the tip of the knife pointing out to avoid cutting the viscera. (Reverse knife technique) and can be made in either direction (up or down the carcase), both of which are shown in the attached videos.

Once the belly is open the White Offal can be removed. The operator reaches inside the carcase and pulls down and frees the bung bag, colon and any connecting tissue past the kidneys and drops these onto the paunch (stomach). Care needs to be taken during this process to ensure the bung bag is not ruptured or removed and any cuts or ruptures in the runners or paunch are prevented so as to eliminate any ingesta spillage, therefore avoiding costly rework by heavy trimming. The weasand is withdrawn through the natural opening at the base of the thick skirt and diaphragm and the runners (small intestine) are freed from the liver. Pressure is then applied to the belly to drop the runners and the paunch in one piece onto the evisceration table. Care needs to be taken to drop the runners first to ensure that they are visible to the Inspectors.

The liver which is still attached to the carcase is then removed in one piece by pulling the top lob away from behind the renal fat and then grasping the liver with one hand and using the other hand to cut the liver away from the diaphragm avoiding any spillage from the gall bladder.

This now leaves the white diaphragm, which becomes the thin skirt close to the internal side of the ribs, and the pluck/red offal underneath. The thick skirt is also still in place.

4.2.2.2 Removal of the Pluck

The diaphragm has a distinctive line between the white membrane and the start of the thin skirt which is generally used as a cutting line by the eviscerator when freeing the skirt. This eliminates yield loss of the thin skirt also eliminates trimming of the diaphragm from the thin skirt. A cut is then made under the thick skirt to release it entirely from the heart and along the spine to release it from the cavity. The lungs, trachea and heart are released by cutting downwards between the backbone and trachea and also severing and removing the dorsal aorta. The pluck can then be dropped onto the evisceration table. The Pluck may also be hung on Offal Hooks, this very prominent in Europe. For non-EU processing, the pericardium is incised and the heart is exposed. It is severed from blood vessel attachments and opened longitudinally and dropped onto the evisceration table. For EU processing, the pericardium is not to be incised, and is performed by the operator on the evisceration table in the presence of an AQIS Inspector.
The kidneys are then removed, enucleated (peeled) from kidney fat and dropped onto the evisceration table so they can be easily recovered and inspected by the AQIS Inspector, or enucleated and left in the carcase to be inspected by the final inspector and then removed by a trimmer.

4.3 System Tooling and design Concepts

4.3.1 Automating the Process

It is clear that the task of performing evisceration manually involves a significant degree of lifting, pulling, handling, judgement and manipulation of the carcase, viscera, tools and various organs/offal. Following a review of the process at the three plants and discussions with John Hughes (John is considered an industry expert having worked in the Australian Meat Industry for over 50 years and been involved in some of the more momentous events in the industry during that period) several points have been highlighted that need to be considered when designing an automated process.

- It is felt that it would be difficult, using a robot, to separate the white and red offal, hence the focus should be on a system that removes both, depositing them on the evisceration table for sorting further down the line
- Removal of both the red and white offal together would require the rodding and sealing of the weasand all the way to the paunch to eliminate the risk of ingesta spillage as the paunch falls out of the carcase.
- The carcase viscera and organs all need to remain correlated as the carcase travels along the line.

4.3.2 System concept

In discussions with John Hughes and following experience obtained during Proof of Concept trials on tooling for small stock evisceration (MLA Project A.TEC.0075, Final Report released in September 2010) it was concluded that attempting to develop a tool that was both able open the belly, pull the bagged bung down into the cavity and eviscerate the carcase would be too complex. The decision was made to have the carcase enter the Robotic evisceration cell with the brisket cut, belly opened and the bagged bung pulled down and resting on top of the paunch. This would then allow a tool to enter the carcase above the bagged bung and move in behind the paunch to initiate removal.

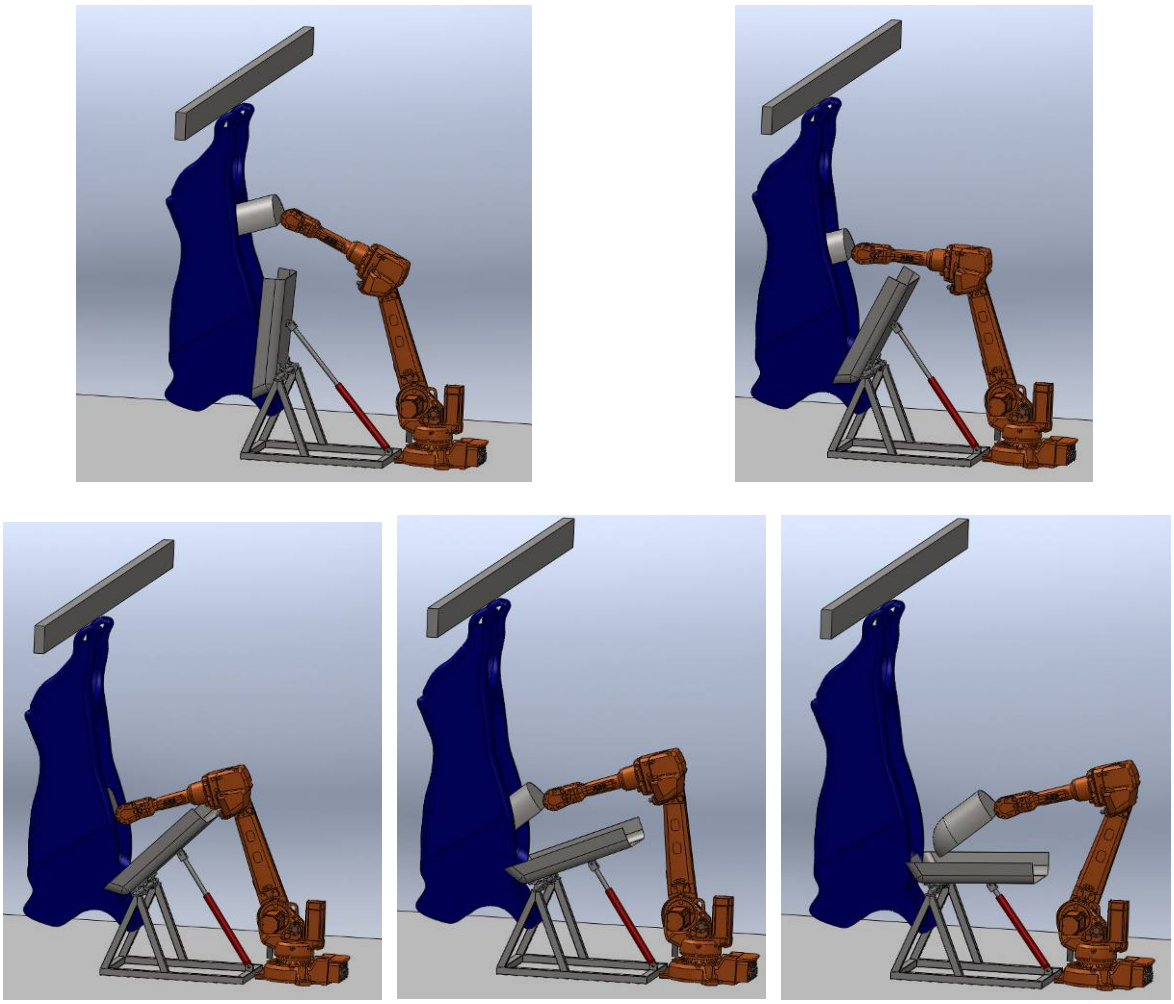

Fig.4 Process concept

With reference to the images above it is envisaged that the evisceration process would be performed as follows:

- The carcase would approach the Robotic evisceration cell with the brisket cut.
- An image would be taken of the carcase to determine its size and correct positions for the tray discussed below and the Evisceration tool to enter the carcase.
- An operator would open the belly and pull down the bagged bung.
- The carcase would then enter the robot cell and an adjustable tray would be actuated under the brisket and tilted up to support the viscera during the evisceration process so that it does not fall uncontrollably out of the carcase.

- This tray would be mounted on a rail such that it tracks and remains aligned with the carcase while it was being eviscerated.

- As the viscera and organs are pulled out of the carcase by the robotic tool this tray/support would be manipulated to collect the viscera and organs and keep them correlated with the carcase. Once the process is complete the tray would be tilted depositing the viscera and organs onto the evisceration table.

- This tray would then be retracted and return to the beginning of the rail passing through a wash station in the process to ready it for the next carcase.

- The robot would also track the carcase from its entry into the cell. Trials will need to be conducted to determine whether the robot will need to be mounted on a rail or the reach of the robot itself will be enough to allow the evisceration process to occur.

- Upon carcase entry to the cell and activation of the tray/support mechanism the robot would enter the carcase and begin the evisceration process with the tool described below.

4.3.3 Tool concept

The image below shows the concept for the evisceration tool.

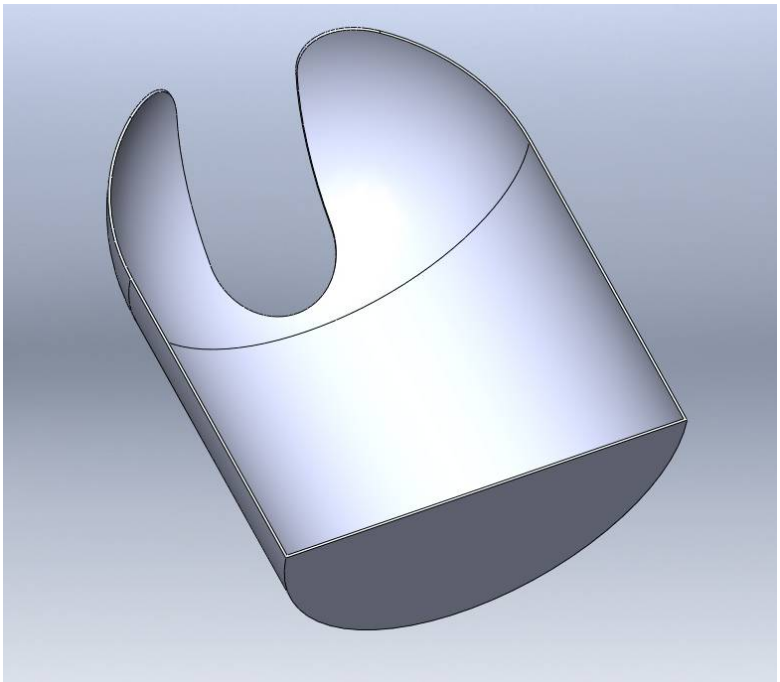

Fig. 5 Tool Concept

It is envisaged that this tool would operate as follows:

- Enter the carcase in a horizontal manner with the open ‘mouth’ of the tool leading until it contacts the back bone of the carcase.
- As the tool contacts the back bone the tool rotates such that the machined slot aligns itself with the back bone and fingers on either side of the mouth ‘straddle’ the spine with the sharper edges of the tool facing the inside of the carcase .
- The robot would then move the tool down the back bone, bringing with it the bung and colon which are resting on the top of the paunch, the kidneys, liver and paunch.
- Once the tool reaches the diaphragm, the robot rotates such that the front edges of the tool contact with the diaphragm and are able to pierce through the diagram at the desired intersection of the diaphragm and the thin skirt.
- Once the diaphragm is pierced the tool would again rotate and run down the spine to remove the heart and lungs.
- The tool would then retract from the carcase, be sanitized in a washtank/spray booth before returning to its home position ready for the next carcase.

The shape and size of the tool requires detailed design but it is felt that this relatively simple concept without any moving parts will be able to successfully eviscerate beef carcases.

4.4 Development Path towards Automation

Concepts for the tool and automation of the Beef evisceration process have been presented. Further development of these concepts need to take the following structured steps, with Go/No Go points to allow the desired outcome to be achieved at the lowest possible risk to all parties concerned.

1. Proof of Concept
2. Online implementation
3. Commercialisation

4.4.1 Proof of Concept

The proof of concept would incorporate detailed design and trials off line of all aspects of the system, the required steps are below:

4.4.1.1 Tool Trials

In this step the concept tool would be designed in greater detail taking into account carcase sizes and angles required to obtain the correct result. The tool would be fabricated and trialled with a standard industrial robot with stationary carcases. This would allow the tool to be trialled off line with carcase hung in a chiller, for instance, where carcases of different sizes could be trialled without interfering with production.
The main aims of these trials would be:

1. To prove the designed tool is capable of correctly eviscerating carcases of different sizes and weights, and whether any modifications need to be made to the designed tool.
2. The cycle time possible with the designed tool and confirmation that it will be suitable for the line speed of the various plants evaluated.

4.4.1.2 Tray Handling trials

The concept tray would be detailed, fabricated and trialled on a stationary carcase being eviscerated by the tool proven in the previous step. The main aim here would be to prove the designed tray structure and mechanism is suitable and effective in controlling the viscera during the evisceration process and depositing it once the process is complete.

4.4.1.3 Sensing capability

This step would be used to confirm that the available sensing technologies are suitable able to provide the correct information to the robot to enable it to enter a carcase with the designed tool and effectively eviscerate.

4.4.1.4 Moving Carcase trials

In this step the tray rail, and wash system would be fabricated and trialled to prove that the proposed system is able to successfully transfer and wash the proposed trays while tracking carcases along a line. This would need to be trialled on a moving rail but not during production hours and once proven would incorporate the trial of the concept tool on a robot performing the evisceration process while tracking the moving carcase.

4.4.2 Online implementation

Once the concept has been proven, it is envisaged that the system will be implemented to a plant as a funded project. The steps here would include

1. Initial design, plant specific layout design and risk identification
2. Detailed system design
3. Purchase of robot system, vision system and control system components
4. System build, setup and trial and the integrators premises
5. Processor acceptance at integrators premises
6. Preparation of site for integration
7. Onsite installation, commissioning and acceptance of the system.

8. Preparation of video and training material and demonstrations to invited audience.

4.4.3 Commercialisation

Commercialisation of the system would include:

- Involvement of further plants prepared to invest in follow up funded projects
- Refinement of design and process to improve the cost effectiveness of the system
- Sales and marketing of the process

5 Conclusions and Recommendations

For this report three plants have been evaluated and the current manual process of Beef Evisceration has been reviewed. Following this evaluation and review concepts have been developed for the automation of the Evisceration process. These concepts incorporate the use of standard industrial robotic and vision systems along with the development of a robotic evisceration tool and tray/support mechanism. It is the recommendation of this report that a proof of concept project be initiated such that further progress can be made in the development of these concepts.