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Technology evaluation for fat removal for beef striploins leaving a uniform thickness behind

FINAL REPORT

Open

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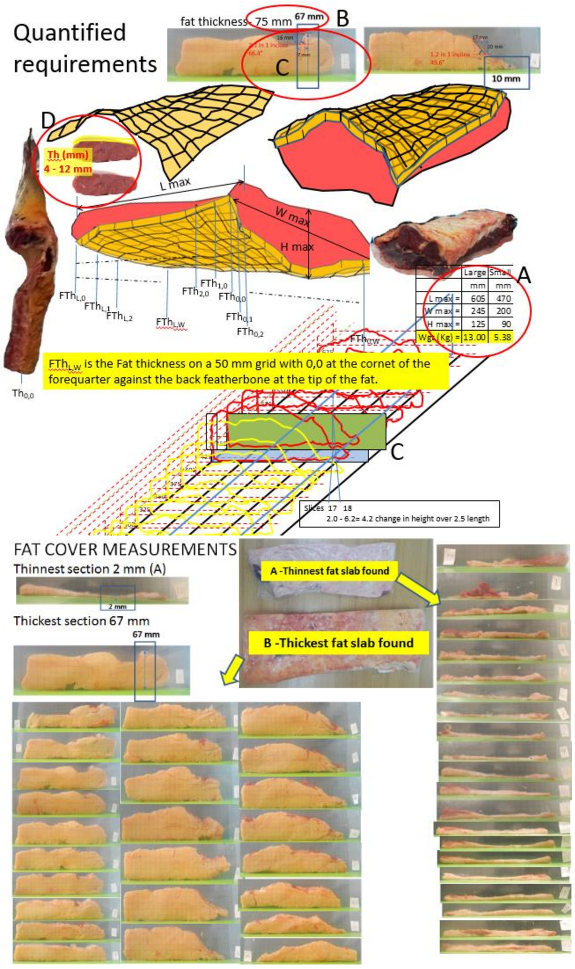
1.0 Executive Summary

This project has researched the processes of fat trimming with the objective to determine automation feasibility to achieve trimming leaving a uniform layer of fat on beef striploin primal pieces.



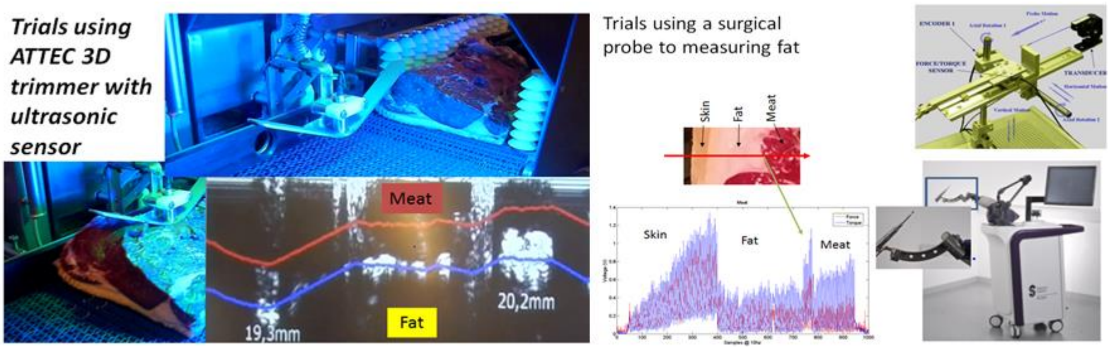
The approach has included the examination of variability of fat cover on beef striploins, taking examples from Australian meat plants and to document the current capability in performing such a task manually on a production line. Evaluation of fat cover sensing technology using ultrasonic, optical and mechanical devises has been a key objective, quantifying their limitations in order to provide at least one type of sensing solution that would meet the requirements in accuracy, speed and integration possibilities with different mechanical trimming arrangements. An important aim of the feasibility has been the trimming methods for leaving a uniform layer behind resulting in the definition of specification and validated concept design of an automation solutions for uniform fat trimming.

The variability in beef striploin has been examined in connection with the processes that would be involved in automatic trimming of fat from de-boned primal pieces. It has also tested viability of fat-meat interface measurements using existing sensors. Of particular interest is the maximum and minimum dimensions of striploin and fat cover as well as availability of proven sensing technology for beef striploin.

Beef striploins range in size and an automated system for fat trimming needs to deal with sizes within a 700 mm length, 300 mm width and 150 mm high striploin dimensions. The fat cover on striploins observed in Australia can be 75 mm in thickness down to 2 mm, with changes in height of fat over meat, within the same primal piece, being as great as 50 mm over a 25 mm distance both along the length and along the width of a striploin primal.

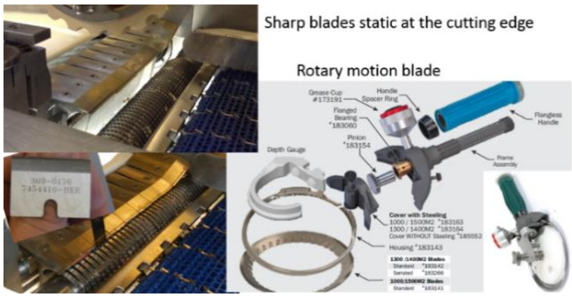
Review of literature, shows that a concept for fat trimming leaving a uniform layer behind was patented over 25 years ago, but no practical equipment has been available to the beef industry. The only machine with similarity available on the market is from ATTEC for pork loin trimming.

The most promising sensing is ultrasonic sensing determining the position of fat and lean interface operating from the lean side. The 3D profile of the fat-meat interface is the main feature of interest and use of ultrasonic sensors has been evaluated with success for beef striploins.



Fat on beef striploins can, in some sections, be delaminate or have air gaps (bubbles) within their structure. The sensing approach measuring fat-lean profile from the lean side, as well as trimming the fat under cross sectional pressure minimizes or avoids complications related to delamination or air bubbles.

Trials have been conducted with sensors revealing that there a number of technologies available, including mechanical probing, but the most promising is ultrasonic sensing for determining the position of fat and lean interface operating from the lean side.



Trimming capability using available technologies has been reviewed in current machines such as the ATTEC 3D Fat Trimmer for pork loins and the wizard hand trimming tools available from companies such as Bettcher or Freund.

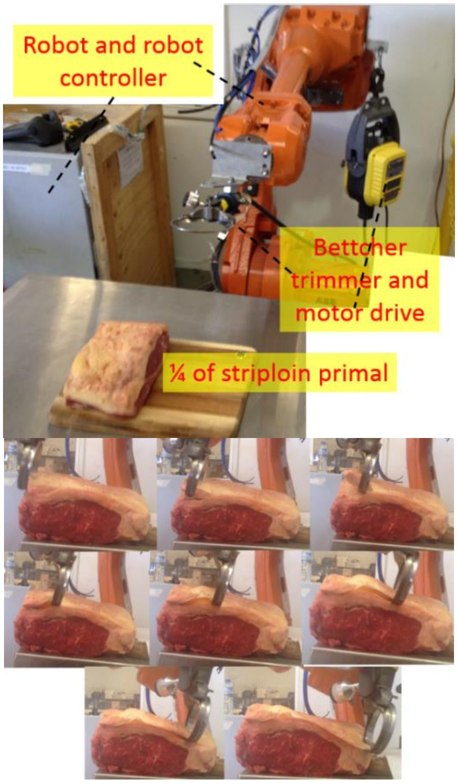
The processes of separation may be achieved by a static blade sharp enough to cause sheering or cutting as meat/fat is forced against it. This is commonly seen in fat removing machines. An advanced form of this in a configuration of a “piano” key arrangement with especially designed static blades next to each other are used in the ATTEC pork loin 3D fat trimmer.

Reciprocating blades or pair of blades working in opposition to each other, where various forms of blade tips are also used. Rotating blade can achieve separation also, commonly used in a variety of machine and powered hand tools.

Evaluations have been made of all such options, with practical fat trimming of Beef Striploin attempted in two specific cases, the wizard trimmer and the static “piano” type blades of the ATTEC 3D trimmer.

The wizard trimmer has capability to remove fat in thicknesses as low as 1 mm and as thick as 12 mm in a single pass at speeds higher than 0.3 m/s. The ATTEC 3D trimmer can achieve the same speed of trimming with static blades, however, trials suggest that the thinnest layer is 2.5 mm as a minimum, but the thickest is 20 mm, due to the machine design and construction constraints.

Fat trimming leaving a uniform layer behind requires the change of cut thickness as the fat trimming process is being executed. The evaluation concluded that both methods (the wizard rotating cutter and the ATTEC static "piano" blades) may be used for trimming fat; however, further evaluations point to an open blade wizard rotating cutter can supports the necessary controllable process given that thicker than 20mm fat will need to be removed in certain cases. Additionally, there is a need to change the angle of line the cutting to achieve closer to a truly three-dimension contour of separation to meet the requirement, a feature that is limiting in the "piano" blade arrangement. It is thus concluded that the approach to reach a working solution requires 3D manipulation of the trimming tool. To this end a test rig has been integrated to further validate the approach.



Wizard trimming used with a robotic or a 3D manipulation could provide the basis for automation with the capability of removing fat in strips of 15-20 mm along the width of a striploin to a resolution of 1 mm at a speed of 20-25 mm/s.

It is concluded that it is feasible for an automated trimming system to perform separation of fat leaving a uniform layer on the striploin, giving users the capability for an effective increase of fat over the area of the primal by at least 1 mm, whilst meeting specification.

The feasibility has relevance to other sectors of the industry in particular lamb where similar loin fat trimming operations require automatic solutions, such as fat trimming of lamb loins for uniform fat cover.

2.0 Introduction

ATTEC Danmark A/S markets the most advanced continuous uniform fat trimming machine for pork. The technology has not been transferable to lamb or beef primal pieces because of the characteristics of pork fat being significantly different.

This project was proposed to assess requirements for fat trimming and quantifying the variability in beef striploin with respect to fat trimming requirements.

The main objective included understanding the following, as related to fat trimming of beef striploins:

- Variability affecting uniform fat trimming process and specific industry requirements in terms of throughput and performances to be achieved.
- Fat cover sensing technology using ultrasonic, optical and mechanical devices, quantifying their limitations; proving at least one type of sensing solution that would meet the requirements in accuracy, speed and integration possibilities with different mechanical trimming arrangements.
- Trimming methods for leaving a uniform layer behind
- Concept design for uniform fat trimming machines.

Methods for fat trimming in the public literature (cross referenced with non-public R&D) include the following:

- Hand tools such as Freund, Bettcher or IBEX (Figure 1)

Figure 1: Hand trimming tools.

- Marel fat trimmer

Figure 2: Uniform fat removal (leaving a non-uniform layer behind).

- ATTEC 3D trimmer

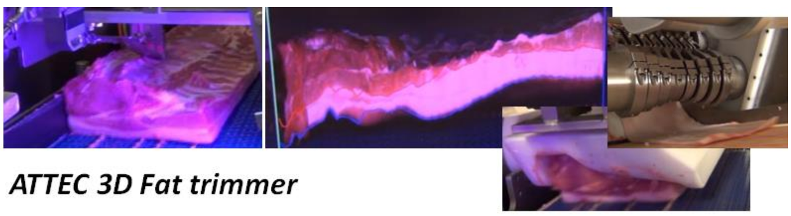


Figure 3: Uniform fat trimming of pork loin primal.

- Bristol Lamb fat cutter (see Figure 4)

Uniform fat trimming of lamb
G Purnell and T Brown

Computers and Electronics in Agriculture 45 (2004) 109–124 ELSEVIER
Received 31 October 2003; received in revised form 12 June 2004; accepted 21 June 2004

Abstract
People are becoming increasingly health conscious and consequently there is a growing demand for lower fat products. For many meat products fat reduction is achieved by manual trimming, however, labour problems are causing manufacturers and processors to investigate alternatives. Water-jet based trimming machines have been on the market for some time but their size and cost limit their usefulness for many manufacturers. Specific equipment for trimming common joints is another option, e.g. automated loin pullers, but such equipment can be too complex or expensive for many meat producers. This paper describes the first stage of research and development carried out to design and build a relatively low-cost demonstrator system for the automatic trimming of lamb chops to leave a user-determined fat thickness remaining. Machine vision provides fat thickness data along the length of each chop. The system then conforms the meat section to place the fat–lean interface at the desired fat thickness from a fixed cutting path. The cutting path is thus simplified and can be made with basic tools and an uncomplicated trajectory. After the cut is complete, the meat section is released and returns to its natural shape but with a uniform covering of fat over the fat–lean interface. Industrial plant trials with the demonstrator system have achieved improved accuracy and product appearance over manual trimming.

Keywords
•Fat trimming; Lamb chops; Adaptive control; Conformation; Food automation

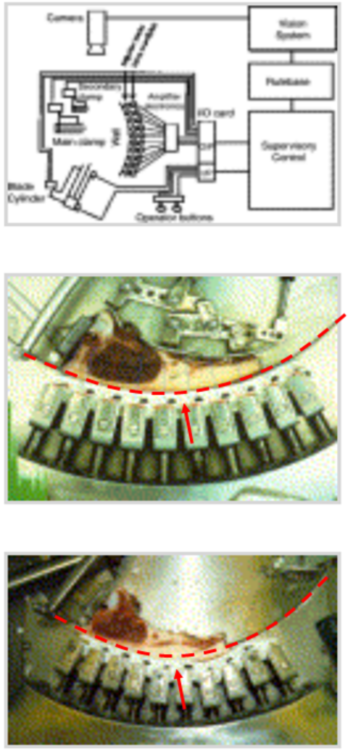


Figure 4: Fat trimming, leaving a uniform layer behind on lamb chops.

The basic concept is to place a lamb chop in a mechanism that forces the fat face of the piece against a known datum (see Figure 4 right, middle photo). A vision system takes and image and determines the thickness of the layer of fat resting against the datum, which can be made to change shape using a series of position controlled actuators. The change of shape is achieved using an algorithm taking the vision system data as input in order to place the line of cut a fixed distance from the edge of the eye muscle - 6mm (Figure 4, bottom right photo dotted line). Note the position of the line of cut (dotted line) as a fixed arc, is made to fall at a fixed distance from the edge of the eye muscle to leave a uniform layer behind, relying on the compliance of the meat allowing it to be forced into shape, whilst positioning it using computer vision information.

The ATTEC 3D fat trimmer is the only commercial solution of fat trimming leaving a uniform fat layer behind. It is designed and used for pork loins. An ultrasonic sensor is used to gauge the fat cover along the length of the loin in conjunction with an imaging system to measure the fat profile along the sides of the loin. The ultrasonic sensor measurement of the fat cover is from the lean side and using the images from the long edge on both sides of the loin to interpolates the fat lean interface relative the fat face on the loin, resting flat on an infeed conveyor.

The machine has a series of computer controlled cutting blades which move up and down adjacent to each other to take a series of layer of fat (side by side in strips) as the loin travels over the blades with the loin on the move. The knives adjust up or down to cut fat leaving a uniform layer behind along each strip based on the information from the imaging and ultrasonic sensor. Note that the loin is held under pressure from the lean side forcing the loin downwards on the conveyor carrying the loin towards the cutter blades.

The ATTEC 3D fat trimmer is the closest solution to what is needed for beef and by exclusive access to a machine at the curtesy of ATTEC in Denmark, it has been used in support of sensing trials for this project.

All attempts for uniform fat trimming have been to take a certain thickness of fat off. The following give an outline of patents relating to beef striploin.

Automatic skin removal and fat trimming device for meat products
US 6244950 B1

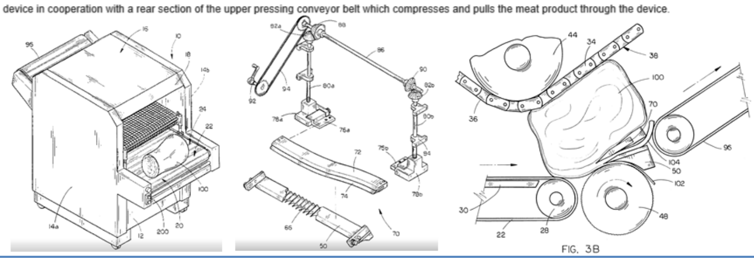
ABSTRACT

An automatic skin removal and fat trimming device includes an entry conveyor belt and a forward section of an upper pressing conveyor belt which cooperate to move the meat product into contact with a rotating ridged cylinder which in turn forces the meat product into contact with a skin removal blade mounted adjacent the end of the entry conveyor belt and a second curved fat trimming blade then engages the meat product, the fat trimming blade positioned above the skin trimming blade and spaced therefrom to engage, cut and remove the fat lining surrounding the meat on the meat product, following which a meat removing conveyor belt mounted rearwardly of the skin trimming and fat trimming blades engages the meat product thus removing the meat product from the trimming device in cooperation with a rear section of the upper pressing conveyor belt which compresses and pulls the meat product through the device.

Publication number	US6244950 B1
Publication type	Grant
Application number	US 09/465,092
Publication date	12 Jun 2001
Filing date	16 Dec 1999
Priority date	16 Dec 1999
Fee status	Lapsed
Inventors	John W. Long, Ryan McGill, Joe LaFave, Aaron Borns, Rick Merrill
Original Assignee	John W. Long, Mcgill Ryan, Lafave Joe, Aaron Borns, Rick Merrill
Export Citation	BiBTeX, EndNote, RefMan

Patent Citations (5), Referenced by (4), Classifications (5), Legal Events (6)

External Links: USPTO, USPTO Assignment, Espacenet



Automated fat trimming system
US 8292702 B2

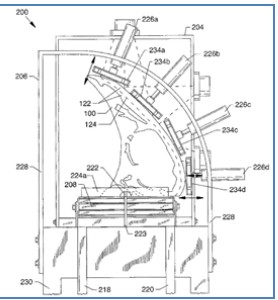
ABSTRACT

An automated system and method for trimming fat from an outer surface of a primal of meat includes a conveyor for advancing the meat, an imaging system for creating at least one image of the meat in order to create a fat profile, and a trimming assembly that removes fat from the outer surface of the meat based on the created fat profile. An orientation device is used to secure and guide the meat on the conveyor. In some embodiments, the orientation device is configured to align with a spinal groove in the meat. In some embodiments, the primal of meat is a short loin; in some embodiments, it is a sirloin.

Publication number	US8292702 B2
Publication type	Grant
Application number	US 13/114,222
Publication date	Oct 23, 2012
Filing date	May 24, 2011
Priority date	May 28, 2010
Also published as	CA2740470A1, US20120108155
Inventors	Thomas A. BOLTE, David R. McKenna
Original Assignee	Cargill, Incorporated
Export Citation	BiBTeX, EndNote, RefMan

Patent Citations (10), Referenced by (2), Classifications (6), Legal Events (1)

External Links: USPTO, USPTO Assignment, Espacenet



Automated classifier and meat cut fat trimming method and apparatus
US 20050079815 A1

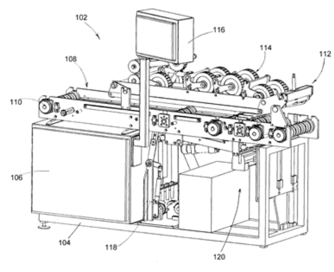
ABSTRACT

An apparatus and method for a meat cut classification and fat trimming for sensing the thickness of a layer of fat of a cut of meat and the various contours thereof as it travels along a conveyance and providing the fat thickness or classification information to a downstream system for performing a fat trimming operation. The meat cut classification system comprises a split/multi-belt conveyor having split/multi-belts proximately spaced apart extending in the same direction and having a uniform equidistant gap there between and said conveyor having a drive for conveying the meat cut through the classification system and a multi-probe mechanism assembly operable to position the probes between the multi-belts of the conveyor and extend the probes upward between the multi-belts to penetrate the meat cut for measuring the fat thickness. The probe assembly is further operable to translate the probe in a direction and at a velocity that is synchronized with the direction and velocity of the split/multi-belt conveyor. This can be achieved by using the same drive for the conveyor and the probe mechanism.

Publication number	US20050079815 A1
Publication type	Application
Application number	US 10/605,294
Publication date	Apr 14, 2005
Filing date	Sep 19, 2003
Priority date	Sep 19, 2003
Also published as	CA2530968A1, 5 More »
Inventors	John Johnson, Chris Vandenbroek
Original Assignee	Tyson Fresh Meats, Inc.
Export Citation	BiBTeX, EndNote, RefMan

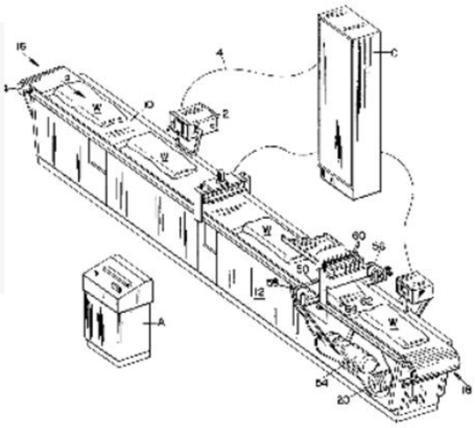
Referenced by (2), Classifications (9), Legal Events (5)

External Links: USPTO, USPTO Assignment, Espacenet



Automatic meat inspecting and trimming machine and method

Publication number	US4209878 A
Publication type	Grant
Application number	US 05/888,006
Publication date	1 Jul 1980
Filing date	20 Mar 1978
Priority date	20 Mar 1978
Inventors	Howard C. Albert
Original Assignee	Albert Howard C



Automatic machine and method for determining the depth or thickness of a layer of fat on a meat section or cut during transport by a moving conveyor, first through a measuring station involving employment of a bank of individually-operable probes arranged transversely of the conveyor travel and intermittently extendable toward and retractible from the meat section, the probes being used to successively measure a plurality of local values in a plurality of sites as they penetrate the fat layer and generate signals representative of those local values for transmittal to and storage in a memory bank as a profile of the fat layer, and second through a trimming station involving employment of an endless band saw having a working run extended transversely of and above the meat section cooperant with means for effecting lateral displacement of portions of the saw blade from the normal reference position responsive to signals from the memory representative of the profile for the prepositioning of the saw blade relative to the various probed sites of meat section preparatory to the trimming of a predetermined thickness of the fat thereat.

The specific patent above, now over 25 years old, is the closest to what has been evaluated by this AMPC project.

Consultations with inventors and the companies leading commercial developments confirm that although some of the elements and thought processes behind the patents above have become practical implementations in machines currently on the market. In fact, none, except the ATTEC 3D trimmer, have reached the level of sophistication to deliver a process that provides for automatic trimming of fat, leaving a uniform layer behind.

For beef no machines are available or in development at the present time, based on the review of current literature, patents and product information.

The challenge and the opportunity will be to design and construct a solution capable of automatic cutting of fat, leaving a uniform layer of fat on the striploin lean, the fat thickness being measured from the fat lean interface to the top of the fat surface over the full area of the striploin primal. To this end, once the striploin is sliced, the slices are to have a specific fat thickness on the face of the slice, the general specification being 8 mm, 12 mm 16 mm or a thickness that is customer specific to ±1 mm.

The project and the results as detailed below, presents the evaluation of the sensing technology as well trimming tools for integration into an automatic solution for fat trimming, leaving a uniform fat layer on striploin beef primal. The ultimate feasibility of the automation, that can provide a technology capability for the Australian meat industry, to perform the task effectively is to be attempted in the Stage 2 of this project following this feasibility.

3.0 Project Objectives

The objectives of this feasibility as originally defined were:

- Assess requirements for uniform trimming fat in beef striploin
- Variability affecting uniform fat trimming process and specific industry requirements in terms of throughput and performances to be achieved
- Definition and validation, by trial, of the correct holding and handling process
- Evaluation of fat cover sensing technology using ultrasonic, optical and mechanical devises quantifying their limitations; proving at least one type of sensing solution that would meet the requirements in accuracy, speed and integration possibilities with different mechanical trimming arrangements
- Evaluation of trimming methods for leaving a uniform layer behind
- Definition of the specification and validated concept design for uniform fat trimming machines

4.0 Methodology

The methodology of the work has been set in 4 milestones, collectively as follows:

- Assess the range of striploin sizes in plants in Australia,
- Observe and document the practice of fat trimming in the current process,
- Obtain industry requirements for trimming beef striploin fat,
- Estimate the opportunity in terms of potential cost benefit from new automation that meets requirements of the processors in Australia,
- Quantify requirements in terms of product and machine capability,
- Review of past developments and current technology, including patent and literature review in the context of fat trimming in the meat industry,
- Specify new process for beef striploin fat trimming based on requirements, observation and previous attempts in parallel sectors,
- Sensing techniques that have been used in the meat sector for fat-meat measurement relevant to trimming,
- Sensing trials to support a practical avenue for automation,
- Consider range of cutting methods,
- Short list options based on practical testing,
- Implement a test rig for mechanical evaluation of automated trimming capability.
- Use trimming tools to identify a tool which provides the capability for controlled trimming to leave a uniform layer of fat behind as a mechanical capability.
- Perform trials with fat trimming in a structured manner, to reach the understanding of the process.

- Establish the basis for a concept solution with potential for development towards a prototype system.

5.0 Project Outcomes

The progress of the project has been as contract and completed on time with the submission of this final report covering the scope of work and results in respect of all Milestones. Work continues under a new contract following to stage 2, which to generate a world first prototype for testing in a meat plant in Australia.

5.1 Range of striploin sizes in plants in Australia

Beef striploin primal cutting involves the separation of the main primal piece from a hid-quarter of beef after separation of the forequarter in the handing position. The primal pieces may have 1 rib or 3. In respect of the assessment of size variation, the work has used 3 rib primal cut pieces as this also covers the single rib situation.

Figure 5, shows the steps in process and the extraction of the striploin primal from a large fatty and a small lean carcass.

Note that the objective here is to establish the range in size that would be a consideration in the process of specifying engineering specification for a machine that would perform fat trimming, leaving a uniform thickness of fat on the striploin lean muscle.

	Large	Small
	mm	mm
L max =	605	470
W max =	245	200
H max =	125	90
Wgt (Kg) =	13.00	5.38

Figure 5: Striploin size variation from whole carcasses.

In Figure 5, the range is measured to be 470-605 mm length, 200-245 mm width and 90-125 height. The range of fat thickness is surprisingly 2 mm in the leanest section of the lean carcass and 67 mm in the fattiest section of the carcass with large amount of fat cover. In the approach to machine design a range of 300-700 mm length, 150-300 mm in width and 60-150 mm in height is recommended.

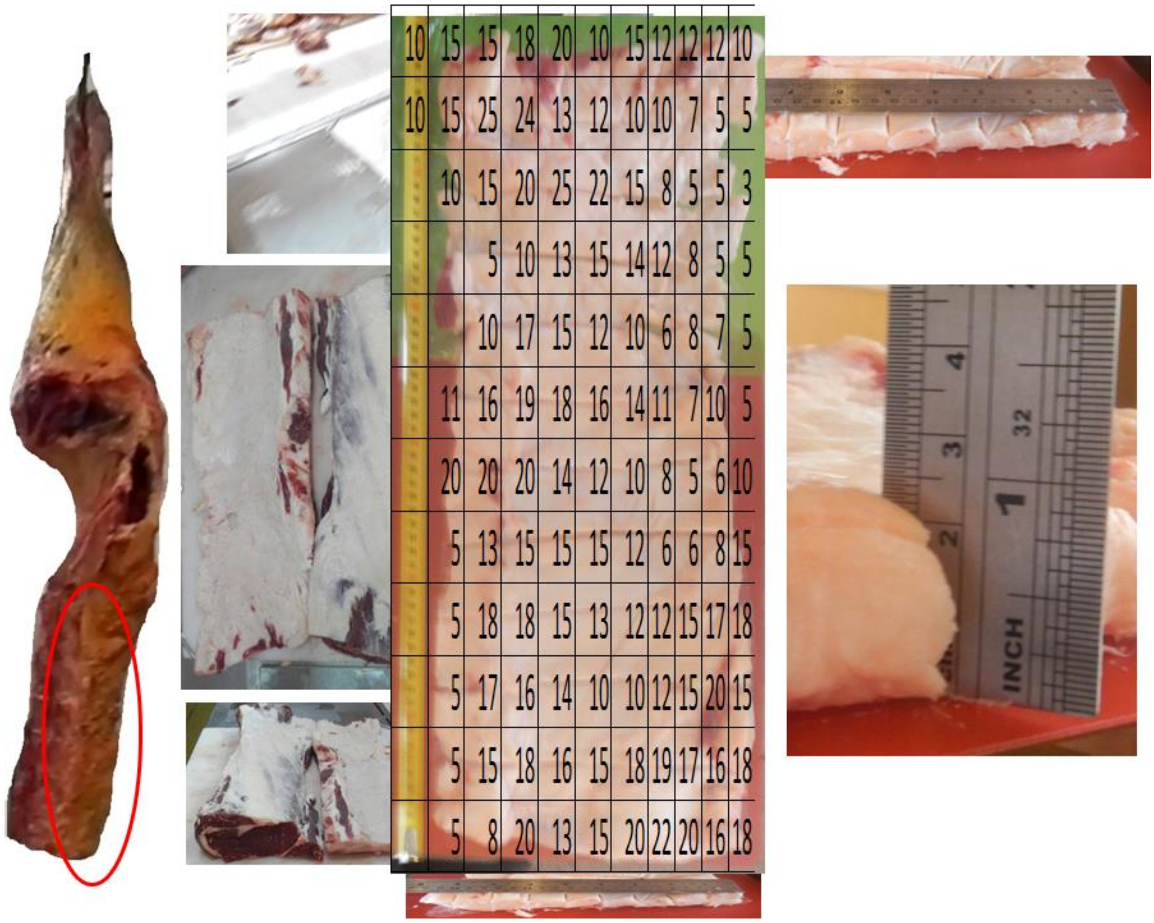


Figure 6: Fat variation in a typical striploin.

Measurements of fat thickness in a nominal size striploin approximately 15Kg in weight may be noted in Figure 6. The measurements were taken by gauging the depth of fat after separating the lean from the striploin and cutting the remaining “slab” of fat in 50 mm strips as shown in Figure 6 (right).

Further measurements were conducted of fat “slabs” from the thin and lean carcasses of Figure 5.

The process of measurement is illustrated in Figure 7, where the slab of fat is sliced in 25 mm sections after squaring off the striploin fat as a “slab”. The slices were placed on under a mm grid transparent film and photographed slice by slice. The images of the cross section along the length of the fat slab for the small and the large striploins are presented in Figure 8.

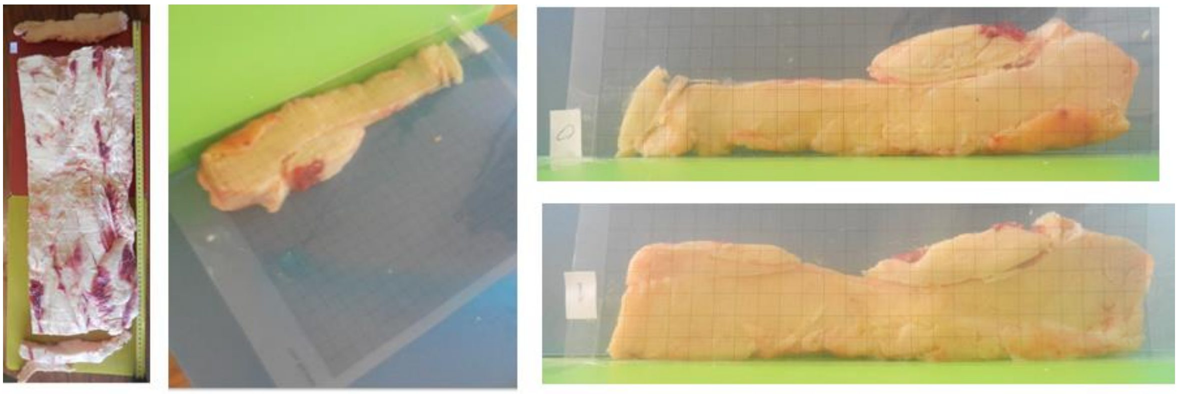


Figure 7: Measurement of fact cover on striploin- example of fattiest striploin.

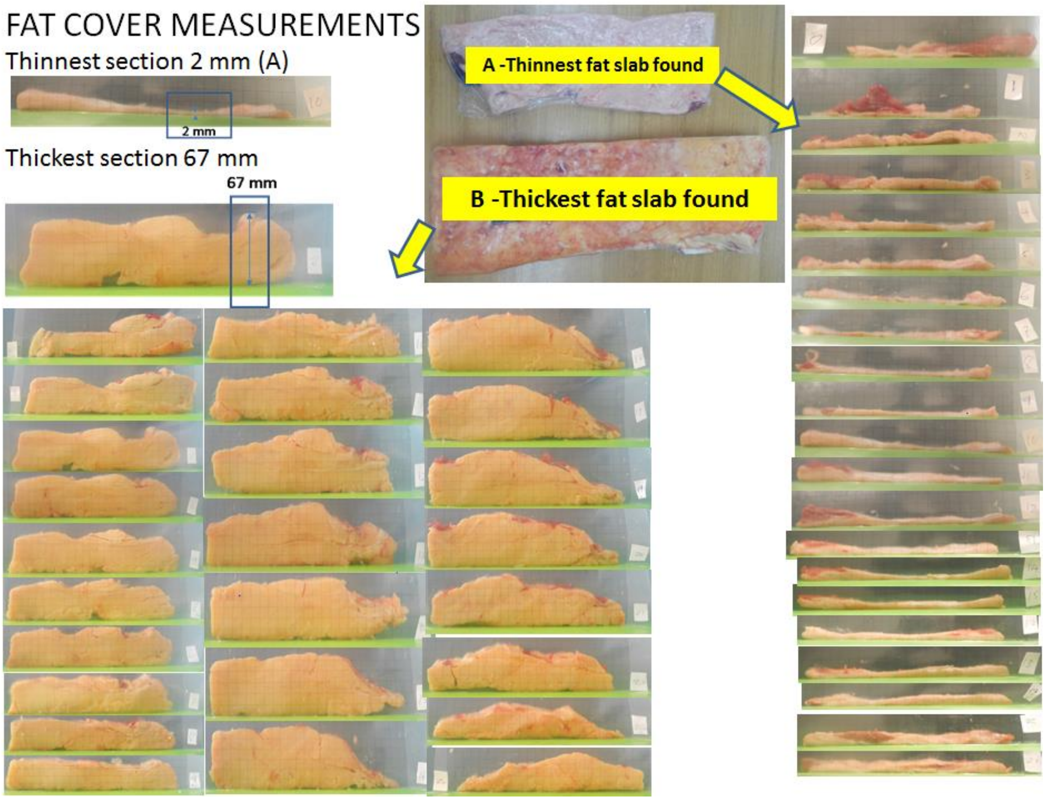


Figure 8: Measurement of fat thicknesses on slices of fat from a thick and a thin slab A and B.

Further assessment of the slices in respect of the thick slab of fat reveals important information in respect of processes being considered for sensing as well as trimming. (It should be highlighted that in the case of the thin slab, the maximum thickness at 12 mm falls can be considered as a situation that would be covered by the assessment of the thickest slab.)

Figure 9, shows the slices from the fattiest striploin in a 3D view as a series of cross section profiles to scale. The surface profile of the slab is shown as a flat piece from the hide-side and also the lean side. It can be seen that both surfaces present significant and what may be considered large variations in thickness, the thinnest section being 10 mm and the thickest 67 mm.

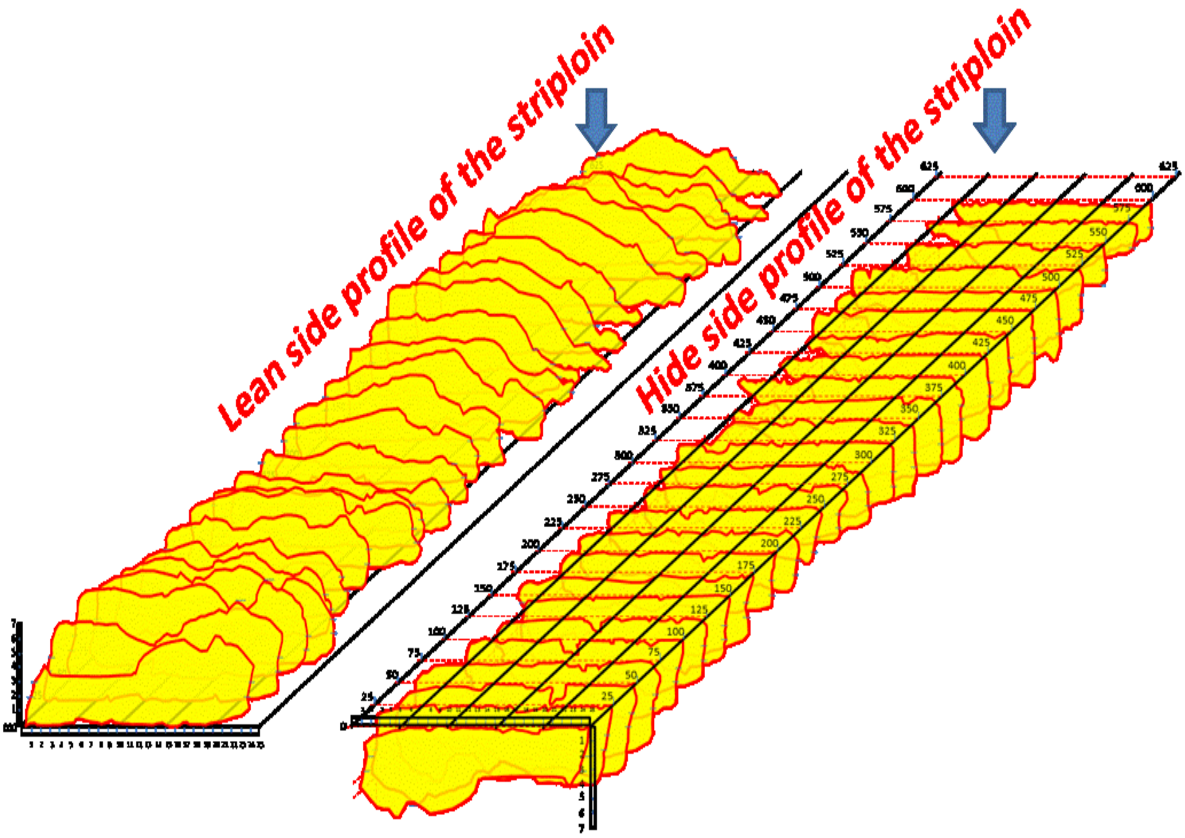


Figure 9: Large variations in thickness on a fatty striploin slab of fat from the lean meat.

The variation in the lean side profile are of particular relevance to the process by which a fat trimming task may be automated. The discontinuities that may be observed from the hide side pose complications to this process as the variation in the contours that can be observed are largely due to the hide separation or pulling processes that pull away the fat in the primary operations of slaughtering.

It is important to note that in the next sections dealing with sensing process, it is concluded that the most appropriate process of determining the fat lean surface profile is for the sensory measurement to be from the lean side of the striploin. The trimming process would normally require the striploin to be held during the cutting action of any blade that is to perform the cutting. The reference for the line of cut requires sensing of the boundary between the fat and the lean, which sensing trails reveal is best performed from the lean side and with the sensor(s) pressing on the meat. This pressure and approach also overcome reported issues with sensing through air bubbles that may be present in the striploin volume of fat as well as delamination issues present in the in fat sections caused by hid pulling. Figure 10 illustrates example of delamination and the approach to sensing. The placement of the striploin with the fat laying on the surface that holds it also provides a reference for the plane of the fat cover, making the sensing process less sensitive to the surface profile variations as observed for the hide side (see Figure 9).

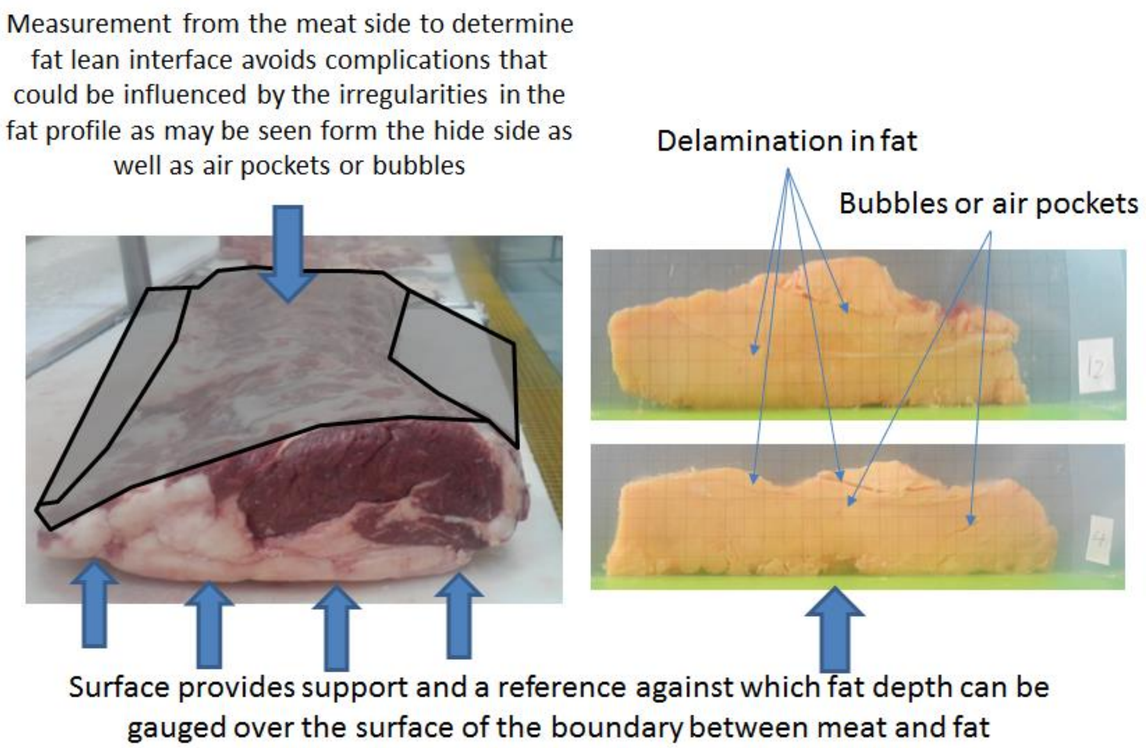


Figure 10: Sensing from the meat side.

5.2 Observation of fat trimming in the current process

Figure 11 presents the manual fat trimming process, which essentially involves knife operations over the surface of the striploin fat with the primal piece resting on a trimming table meat side down. The knife actions are controlled as best of possible by a skilled or trained member of the cutting room team. This person uses the senses of touch and vision, combined with "experience", which includes a mental model of the profile of the striploin anatomy.

The skill in the trimming process involves judgement of the path of the knife as it is pushed though the fat cover (see Figure 11) to remove a layer and then another layer, until the sense of touch and visual observation suggest to the person trimming that no further fat cutting action is necessary and the fat cover has reached a thickness that meets the specification. This specification is in the range of 4 mm to 12 mm ± 2mm. The nominal fat cover is reported to be 8 mm ± 2 mm.

It is clear that manual cutting has its limitations to meet the specified uniformity in fat cover that would be left behind in a consistent manner. The key requirement is thus to achieve a user defined fat thickness on 90-95% of the striploins being processed to within ±2mm tolerance, with the remaining percentage not meeting specification only due to the initial fat cover not being thick enough for trimming to a lower thickness of the thicknesses of fat are such that the economics of making a machine that achieves the accuracy required at a more consistent throughput and fat or fat trimming rate, would place the level of investment beyond industry acceptable period for return on investment.

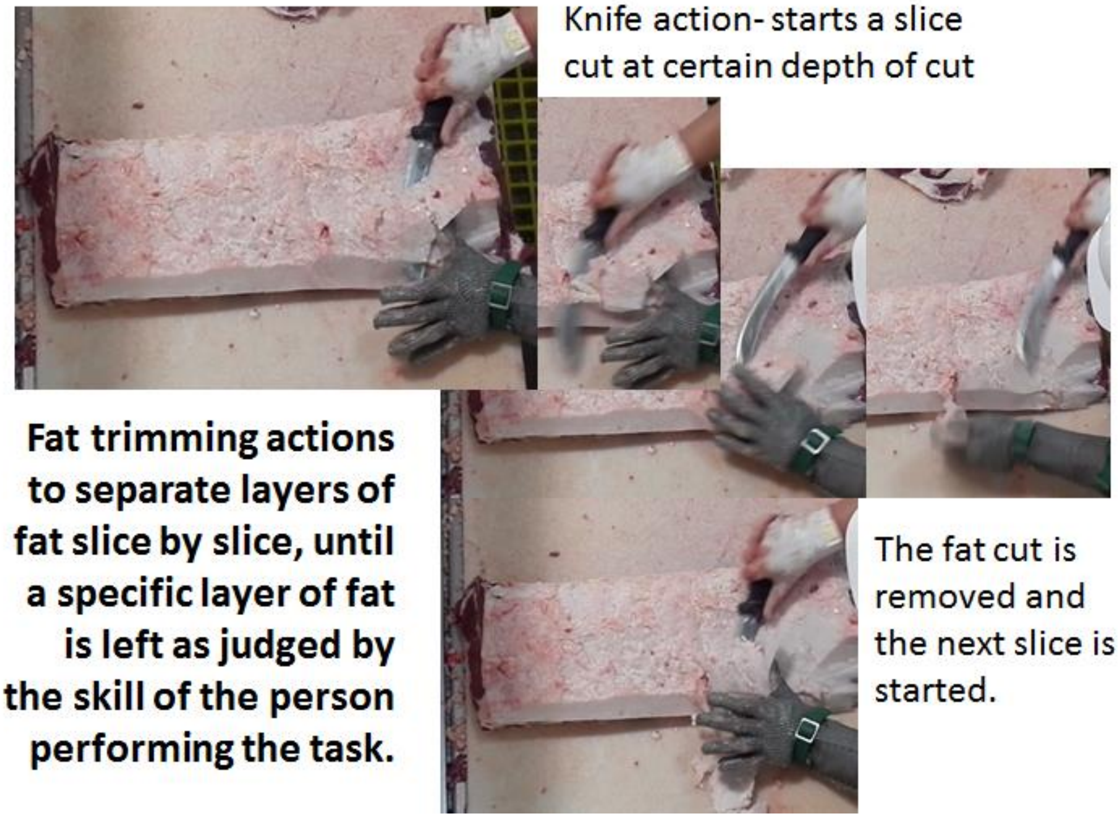


Figure 11: Fat trimming process as performed manually.

The manual process as observed can be inconsistent resulting in most cases if not all cases in over-trimming of the striploin.

5.3 Industry requirements for trimming beef striploin fat

The main requirement is to leave a uniform layer of fat on a striploin primal in such manner that provides a specific thickness of fat on the eye muscle of a pieces of sirloin (or porterhouse) after the primal piece is sliced.

The expected fat cover uniformity is nominally set to a tolerance of ± 2mm in the range of thicknesses from 4 mm to 12 mm.

It is expected that the uniformity is achieved for better than 98% of cases. Note that fat thickness coverage of greater than tolerance results in customer rejects, complaints and claims. Under size thickness results in loss of value on the primal for the processor in weight of striploin resulting in financial losses.

5.4 Estimation the opportunity- cost benefit from fat trimming automation

A machine that performs fat trimming leaving a uniform layer of fat on a striploin primal may be justified on the basis that it will result in greater consistency to leave that target thickness of fat and to within the nominal tolerances.

In the overall scheme, the aim would be to ensuring that, on average a 1mm fat thickness can be the increase on the thicknesses achievable compared with manual processes, for a much higher percentages of striploin volume of production, in a typical meat operation.

Figure 12 illustrates a first estimation of the weight of 100mm by 100mm fat of 1 mm thickness. A block of meat is measures and the volume and weight provide this weight estimation.

Market trends to fat cover on meat

1 mm beef weight on Striplion and value		
A	72	L - length
B	16	W - width
C	18	H - Height
D	20736	Volume mm cubed
E	17.22	gs total
F	0.000830	g/mm cube
G	**8.30**	**g/mm thickness over 100 sq mm**
H	Striploin dimensions	
I	200	min width
J	470	min length
K	94000	mm sq. surface area of fat on min size prima
L	**78.1**	**g weight of 1mm fat on min size primal**
M	2	primals per carcass
N	60	carcasses per hour
O	7.5	hours per day
P	5	days per week
Q	50	weeks per year
R	225,000	primals per year
S	17,564	Kgs per year
T	15	$ per Kg
U	**263,457**	**$ per year on one shift**

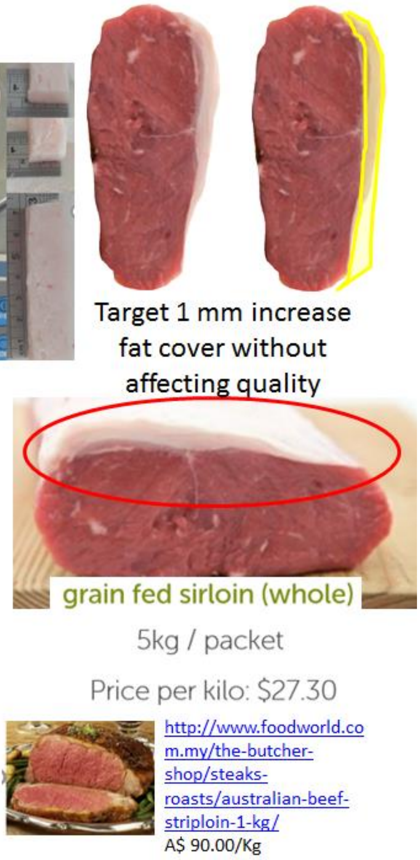


Figure 12: Conservative estimation of fat thickness control benefit in AU$.

A block of fat 72mm long, by 16mm, 18mm cross section has been weighed at 17.22g. This gives the weight at 8.3gs for a 1 mm thick 100mm by 100mm size fat. Based on this figure, Row S, Figure 12 shows the calculation of 17,564 Kg, the weight of 100 mm square of 1mm thick fat for 225,000 primal pieces, which equates to 60 carcasses per hour, 5 days per week 50 weeks per year on a single shift. At a conservative pricing of AU$/Kg pricing for beef striploin, the value of a 1 mm fat on a typical piece of 200mm wide and 470mm fat cover striploin would be over AU$ 260k.

If on average a machine were to result in fat trimming with 1mm added to the thickness of the fat striploin primal pieces on two shifts at 120 carcasses, then the benefit would be as high as one million Australian Dollars, conservatively estimated.

5.5 Quantification of requirements in terms of product and machine capability

Figure 13, quantifies the requirements in terms of:

A. Range of primal striploin size 605 mm in length,245 in width and 125 in height
B. Range of fat thickness 67 mm, but this may be as high as 75 mm
C. Maximum changes in fat thickness whilst traversing along the length (4.2 mm change in thickness over 2.5 mm – close to 60 degrees) or width wise 66 degrees.
D. Target thickness of fat cover 4-12 mm ±2mm

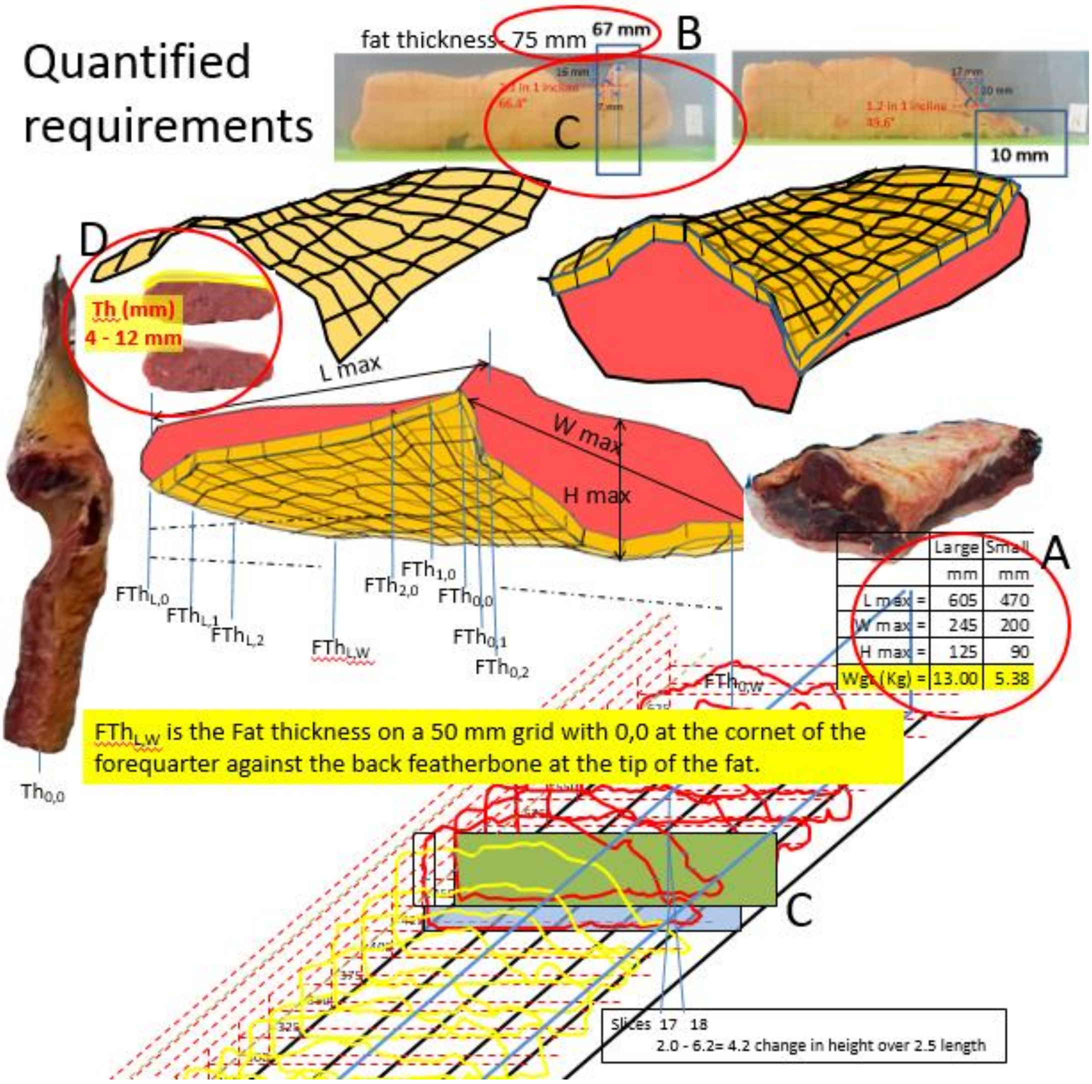


Figure 13: Quantified requirements.

A machine or automated system for removing fat leaving a uniform layer needs to accommodate the sizes of primal pieces and, in particular, the fat cover thickness range 2 mm to 6 mm. such a machine would be a first in the world if it were to be fully conceived by this feasibility. The next section provides an overview of machines and concepts that have been attempted for trimming fat in a manner that compares with the manual process, taking layers of fat off a beef striploin, but non that meet the requirement to leave a uniform thickness fat layer behind. An automated process for beef striploins fat trimming, leaving a uniform fat layer behind for the Australian Processors need to have a minimum throughput capacity of 240 pieces per hour.

5.6 New process for beef striploin

Based on the information presented so fat in this report, the challenge of fat trimming to leave a uniform layer has been established. In particular, the range of fat cover thickness and profile variability assessment demonstrate the complications and the complexities that need to be understood and overcome in order to reach a practical solution.

Given the range of fat cover thicknesses naturally present in carcasses and in the primal striploin pieces from the same carcass, it is envisaged that a twostep process needs to be considered for separation of primal striploins with fat cover of 12 mm maximum thickness and those greater than 12mm. For the latter, a coarse fat separation, but controlled trimming is proposed to bring the thickness of fat cover down to 16mm maximum with a tolerance of ±5 mm as a step one. A process that then accurately senses and trims fat to a uniform layer to meet customer specification 4 mm to 12 mm ±2 mm would then follow as step two.

The focus of the next sections will be to consider the sensing capability identifying at least one technique that would provide a solution to meet the requirements of the project as a practical option.

5.7 Sensing techniques for fat-meat measurement relevant to trimming

Several methods for measuring fat thickness in meat pieces have been in practical use within the industry.

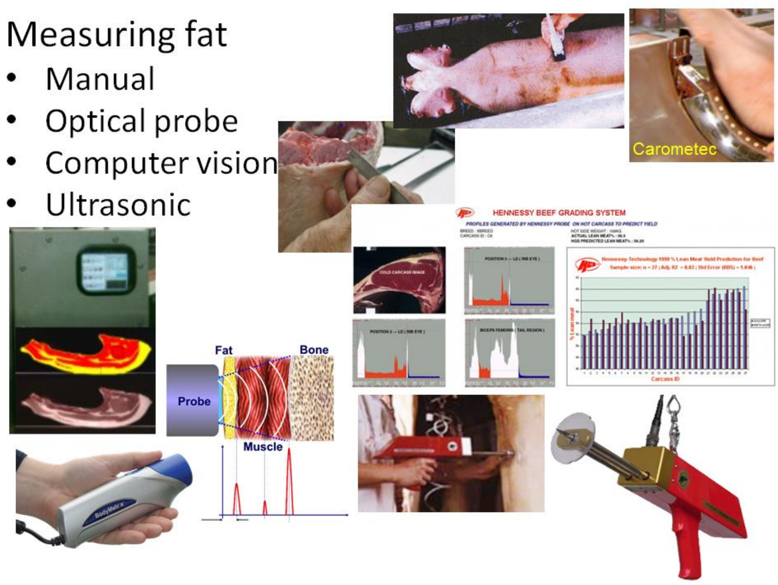


Figure 14: Fat measurement techniques.

Ultrasonic sensors, optical probes and computer vision systems are automatic means of measuring fat thickness as Figure 14 illustrates. Indeed, several of the machines on the market

(ATTEC and Marel presented earlier) use such devices to measure fat thickness, particularly on pork.

The Hennessy Probe, Figure 14 bottom right, is in daily use for measuring and classifying fat.

A rotating tool, developed for surgery is also reported to give tissue discrimination capability.

As a precursor to the continuation of the project, it is necessary to demonstrate, explicitly for beef that at least one sensing technology capability will provide the desired measurement for fat-lean profile measurement in beef striploin pieces.

The next section presents the test cases complementary to the Hennessey probe technology, which is a proven process for beef.

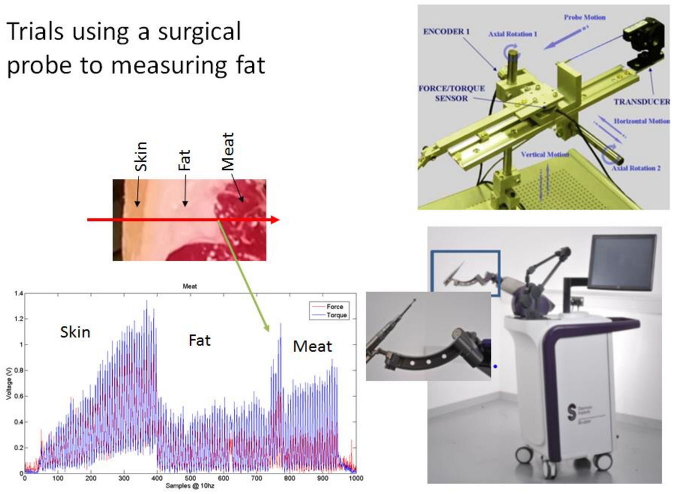
5.8 Sensing trials performed to support a practical avenue for automation

Two trials have been conducted:

- Rotating Surgical tool at the University of Brunel, Uxbridge, UK with Professor Peter Brett, who has pioneered this technique for tissue discrimination and characterization.
- Ultrasonic measurement of fat thickness currently in use within the ATTEC 3D trimmer for pork.

Figure 15 presents the trial performed in order to determine the feasibility of using a rotating tool used for tissue discrimination in surgery, for detecting the boundary point between fat and meat tissue in a block of meat.

The probe uses, force sensing in the direction of the probe motion (top right image, Figure 15) and the torque, and based on tissue models for such tissue types, it can detect the fat-lean boundary point before actually reaching it physically by the trip of the tool. Figure 15 shows the point at which the signals peak when reaching the lean meat from fat.



<u>Figure 15: Trial with surgical probe at Brunel University</u>

Although the “surgical rotating tool” is capable of detecting fat-lean interface it is slow and similar to the Hennessy probe and other similar penetrating tool, they pose a risk due to the fact that a metal piece has to penetrate the striploin piece to provide the information for trimming.

Non-invasive methods would therefore be preferred, which also provide for the process of sensing to be performed with the striploin on the move.

Figure 16 shows the results from repeated testing from the same piece of beef striploin with the ultrasonic sensor on the ATTEC 3D trimmer, which was especially set up for this test, but without any software or hardware changes.

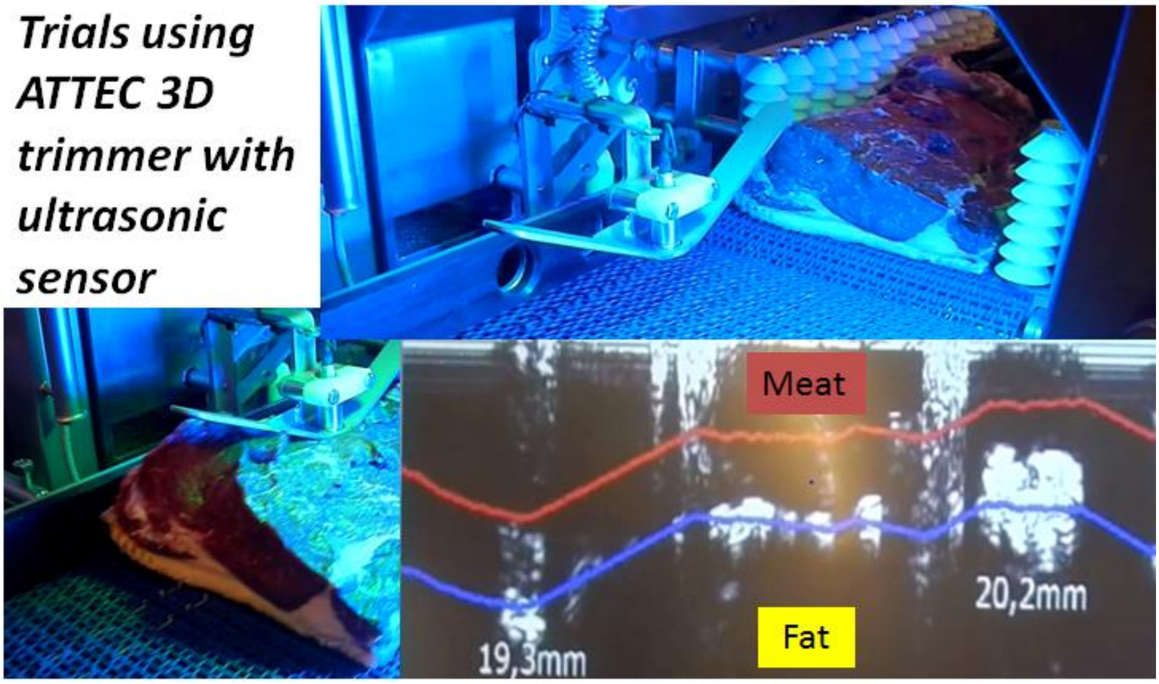


Figure 16: Ultrasonic sensing trial using the setup of the ATTEC 3D pork loin trimmer- multiple passes produce consistent measurement at two sample points for beef striploin.

The key finding of the trials were:

- Ultrasonic sensing provides the most appropriate non-invasive solution
- The tests with the ATTEC 3D equipment reveal consistency and correct measurement
- Ultrasonic measurement for determining fat cover profile for beef striploin is practical and successfully tested
- The sensing from the meat side provides a realistic solution, with the possibility of controlling the fact surface on a conveyor and pressure from above cutting the fat from underneath away from the sensors.

5.9 Cutting options

Figure 17, shows the different cutting processes that may be used for separation of fat.

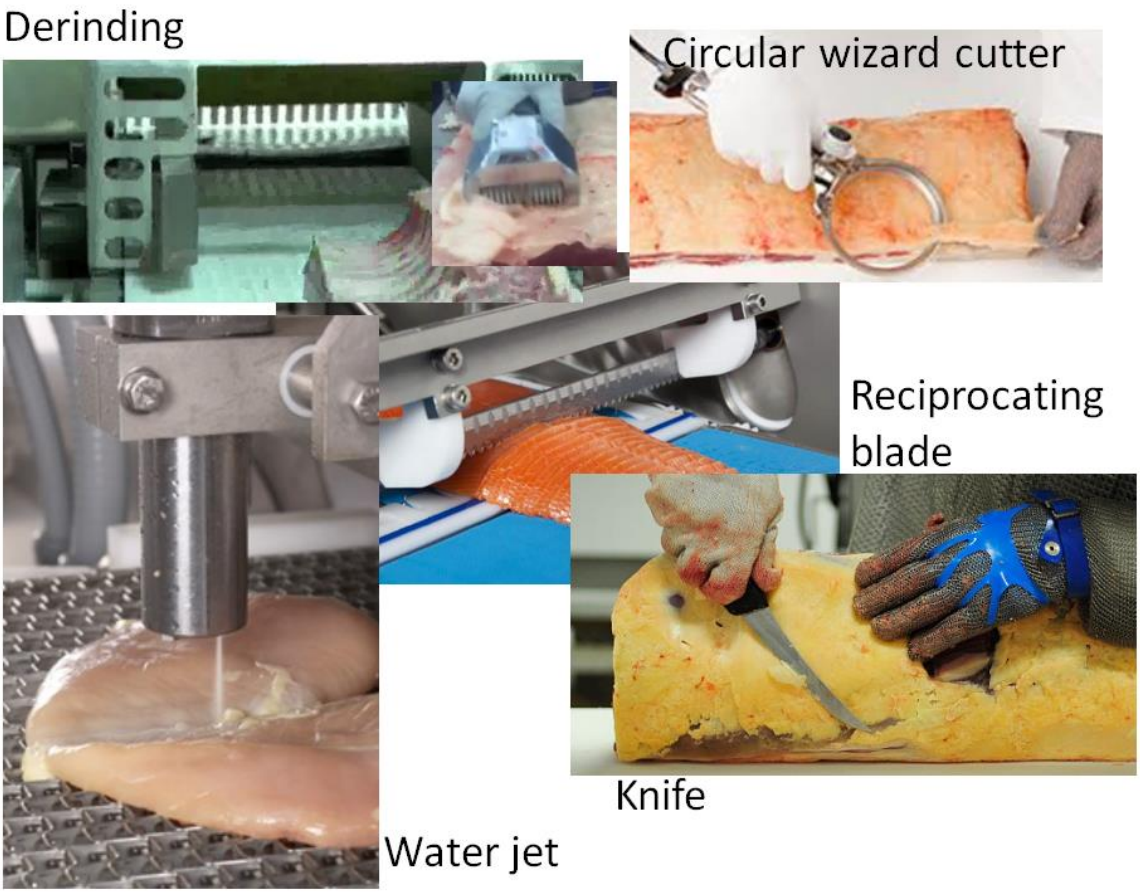


Figure 17: Cutting mechanisms.

Use of simple knives, reciprocating cutters, water jets and other forms of cutting including wizard and drum briskets cutters as hand tools have been available for many years and several are in use in the cutting of beef fat, including striploin fat trimming.

The cutting of fat to leave a uniform layer beyond is a complex process as a manual operation, especially on striploin primal pieces where tolerances in thickness to within ±1 mm is a requirement specification for some customers. The complication of determining fat cover from external visual and/or feel is a near impossible tasks, let alone the capability to achieve physical cutting of fat separating the target layer that leaves the desired thickness of fat behind to such tolerances.

5.10 Boundaries of the trimming process

In the manual trimming process, the natural manner in which fat is cut from above with the primal piece lying flat on a cutting table.

Figure 18 presents examples of the manual trimming arrangements.

Figure 18: cutting of fat by hand.

Using such tools as shown in Figure 18, manual fat trimming is performed with the skill capabilities that sense the position of the fat surface of a primal piece, resting on a cutting table, traversing a cutting edge of a blade (static or powered) over the surface with a depth penetration that removes a layers of fat. With the derinding barrel trimmer (left) and the wizard cutter (bottom right), the thickness of the layer being removed may be set. Evaluation of the options to set this thickness will be presented later in this report. It is important to note that the surface of the fat may rest at different heights above the cutting table because of the variability and non-uniformity of the overall primal piece thickness. In manual cutting, the judgment of the person performing this allows for this variable position to be accommodated. However, in a machine, measuring the overall primal piece thickness presents yet another complication in addition to sensing of the fat thickness. To this end, and based on this qualitative evaluation, it is envisaged that the most appropriate approach for automatic fat trimming would be to have the primal piece with the fat resting flat on a surface. This is already apparent in the ATTEC 3D fat trimmer. Furthermore, the process of sensing may be from the meat side, measuring downwards by ultrasonic, where the thickness of the fat may be referenced to the flat surface on which the whole primal fat cover may rest or be forced to rest. In this manner the cutting process will be required to respond to changes in fat profile relative to the fat-lean interfaces over the area of the fat cover, that have a simple datum, a flat surface. This is illustrated in Figure 19.

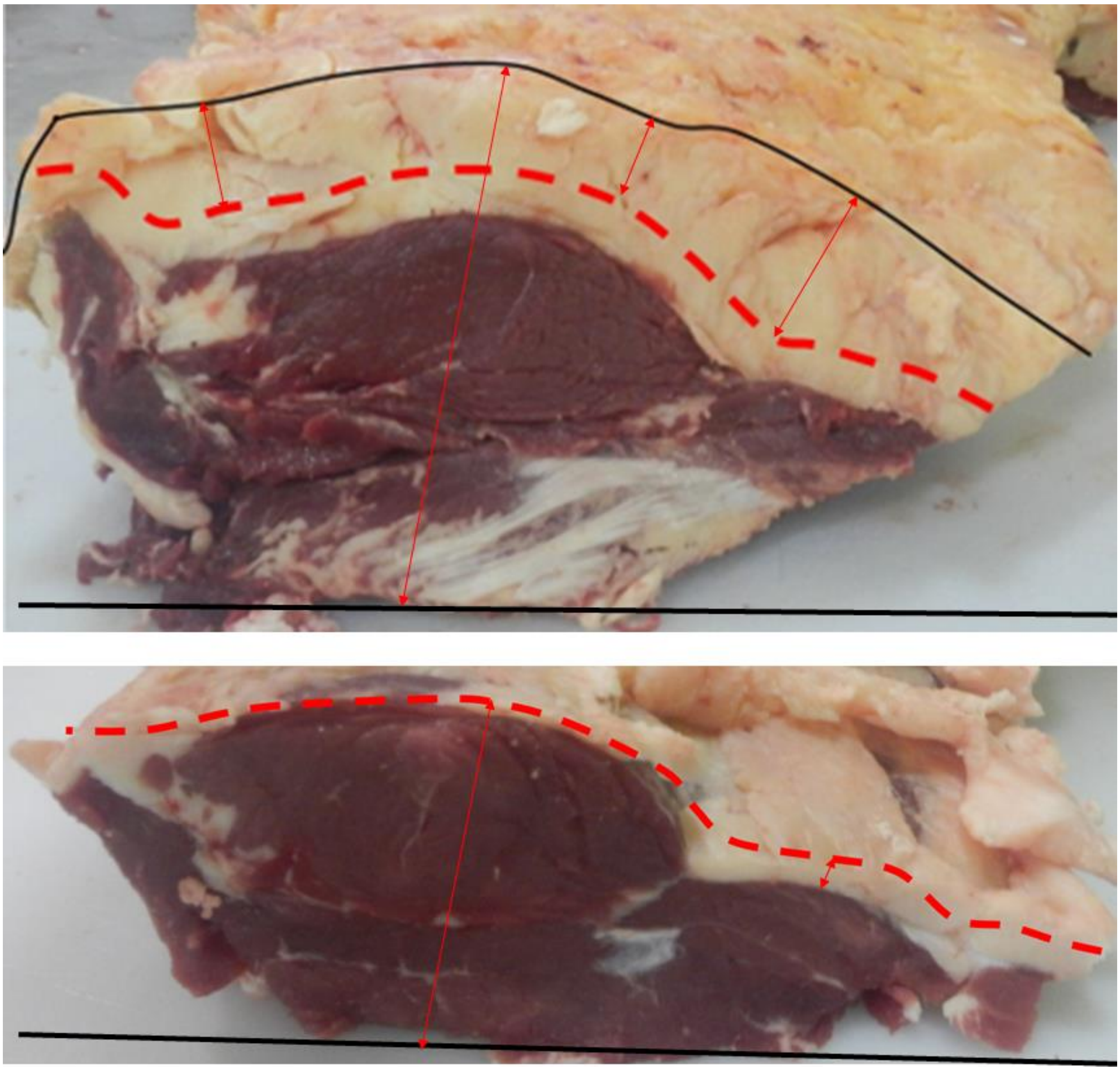


Figure 19: Primal piece height variability poses complications for automation over and above the fat thickness variation with primal orientation as shown.

By placing the meat side of the primal piece on a flat surface, applying downward force from the far side, a datum may be established. This is important both during the measurement to determine the fat-lean interface profile and during cutting, taking layers of fat relative to the datum set by the surface on which the primal piece rests. Sensing would be from the meat side ahead of the trimming in appropriate sections.

5.11 Evaluation of cutting tools by practical experimentation

Evaluation of the ATTEC 3D trimmer cutter blades and the Bettcher wizard cutter has been made as these represents the two possible options for making the separation in beef striploin fat. Observations of other cutting processes reveal that these two cutter types provide the most promising tools for fat cutting in the manner anticipated. Figure 20 illustrates the blades.

The ATTEC “piano” style array of blades adjusts in the vertical direction to cause separation as the primal piece is driven onto the toothed drum be a conveyer delivering the primal after scanning of the fat profile has been performed. Note the meat is facing up and the fat cover surface is flat on the infeed conveyor. The height of the blades above the drum wheel determines the thickness of the fat removed.

The Bettcher tool has a rotary blade that sits within a housing and a nylon guide which resides inside the knife cutter. The distance between this guide and the tip of the circular powered knife determines the thickness of the fat.

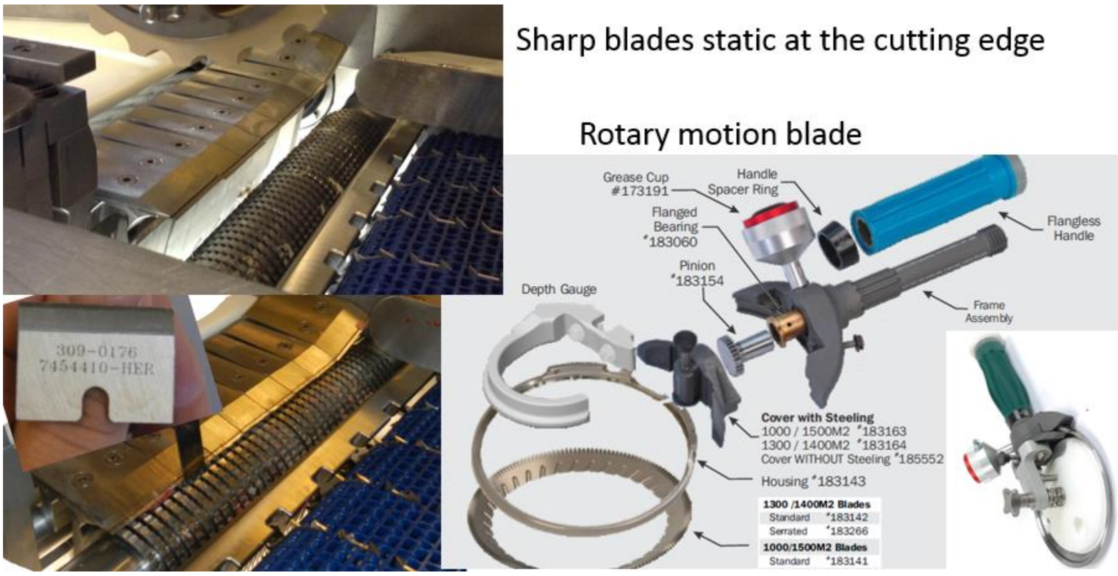


Figure 20: ATTEC 3D “piano” style cutter and the Bettcher rotary powered hand tool.

ATTEC 3D trimmer:
20 mm max thickness
2 mm minimum thickness
1 mm resolution in thickness
Step changes along the cutting edge need to be avoided.
Blades are set to take a whole width 250 mm across the primal.

Bettcher trimer:
13 mm max thickness
1 mm min thickness - infinite resolution
Angle or of tool relative to surface or pressure have negligible effect, but should be kept fixed. The width of a section can be 40-60 mm in a given pass.

Figure 21: Practical evaluation of the ATTEC 3D cutter and the Bettcher tools.

The main requirement to leave a uniform layer of fat on a Beef striploin primal would require an arrangement that has a more controllable 3D capability, than offered by the ATTEC 3D cutter or the Bettcher hand tool used in a conventional manner. Figure 21 presents the evaluation of both cutters in practical experimentation.

5.12 The desired cutting process

The evaluations and the considerations of the requirements reveal that the process to trim fat from beef striploins leaving a uniform layer behind required a more controllable three-dimensional separation mechanism for cutting.

Figure 22 presents the challenge using images of the end profile of average thickness fat cover beef striploin primal pieces.

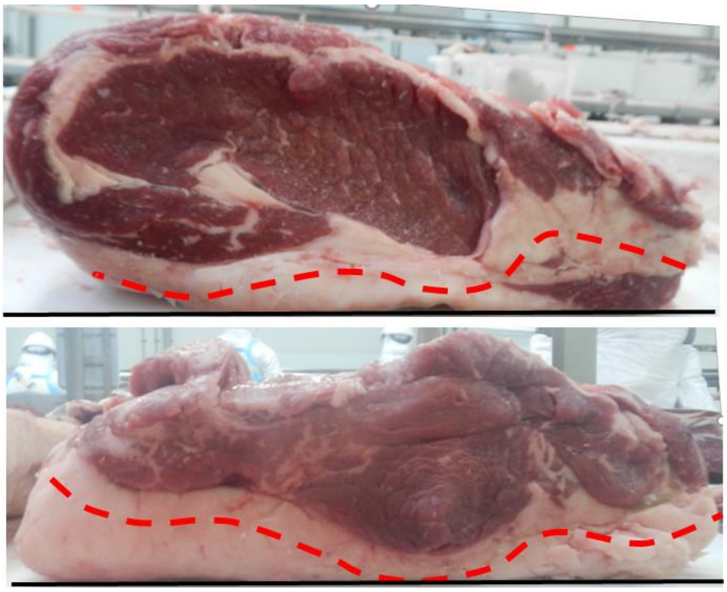


Figure 22: Uniform fat layer - cut profile across the primal pieces is shown in broken red lines.

The process requires a blade to change shape along the width of the primal and whilst travelling into the fat, the path of the cutter also needs to change up or down to keep the thickness remaining on the meat uniform as the cutting progresses along the length of the primal. It may be seen that the "piano" type static blades of the type used in the ATTEC 3D Trimming Machine for pork loins would only give an approximate profile. The dotted red line marking the profile in the cross section has sharp gradient changes. These changes imply that "piano" cutters would be required to change angle about the axis of the blade in addition to moving up and down.

A more relevant approach could use the wizard cutter with the capability to change the thickness of the cut as well as angle about the axis of travel into the primal along its length as illustrated in Figure 23.

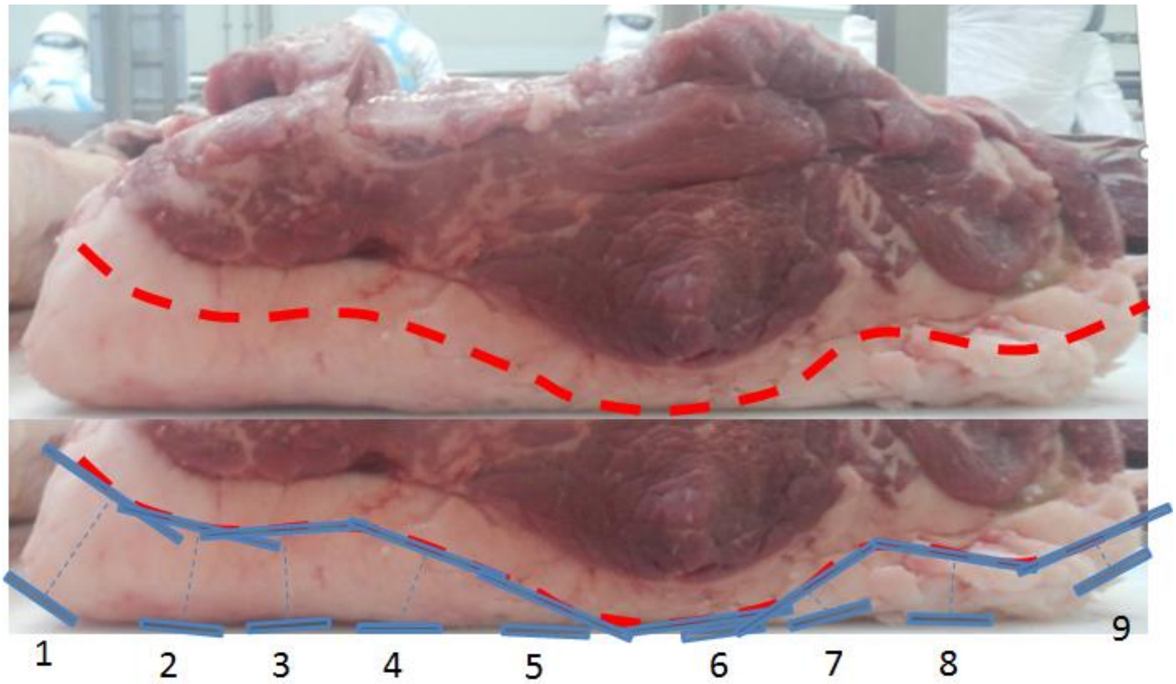


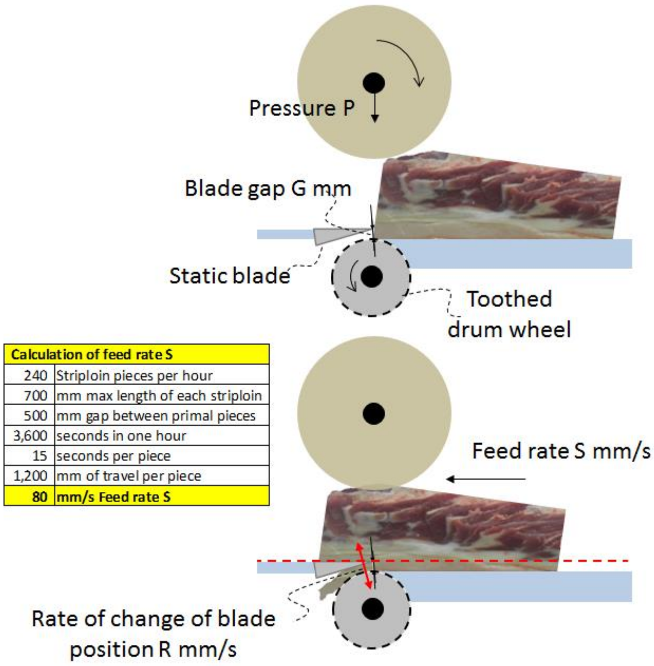
Figure 23: Removing fat in for specific thickness requires change of cutter depth and angle.

To achieve the cutting of fat leaving a uniform layer behind, Figure 23 shows the starting thicknesses from position 1 to 9 along the width of the primal. The depth cut may need to be achieved by several passes along the length. At positions 5 and 6 there is little to be removed, but as the knife traverses along the length, the thickness change may be such that depth of cut may have to change to remove the necessary fat for a uniform thickness to be left on the lean.

In addition to the control capabilities to achieve the correct cut depth, it is necessary to perform depth settings at speeds compatible with the speed of primal infeed and fat separation at speeds that meet production throughput.

The evaluations highlight the need for first pass trimming to achieve fat trimming to leave a uniform fat layer at maximum thickness initially as a first pass. A second scan by sensing would provide for trimming in a manner that takes a thicker layer off, but with minimum depth of cut adjustment leaving a more accurately defined uniform layer behind.

As a concept, Figure 24 presents the main cutting parameters for a machine solution with a throughput capability that meets with the requirement of 120 carcasses per hour or 240 beef striploins per hour.



Calculation of feed rate S	
240	Striploin pieces per hour
700	mm max length of each striploin
500	mm gap between primal pieces
3,600	seconds in one hour
15	seconds per piece
1,200	mm of travel per piece
80	mm/s Feed rate S

Figure 24: Desired cutting process and approach to the next development.

6.0 Discussion

The project has provided a clear quantification of the variability of fat in beef striploin primal pieces, whilst presenting the practice and potential process for automation.

In particular, use of ultrasonic sensing combined with capabilities in mechanical trimming technology can be integrated to achieve automation for trimming fat based on the trials performed. Trimming longitudinal along the primal is considered less effective than trimming across the width of the primal piece. This is compatible with the slicing process that generally follows, where slices would have a uniform fat cover on both faces of the lean meat.

7.0 Conclusions/ Recommendations

The project has reached the following conclusions:

- Quantification of the requirements for beef striploin fat removal leaving a uniform layer of fat behind.
- Review of literature, showing that the concept was patented over 25 years ago, but no practical equipment has been available to the beef industry. The most recent and the only machine available is from ATTEC for pork loin.
- Trials with sensors reveal that there a number of technologies available, but the most promising is ultrasonic sensing determining the position of fat and lean interface operating from the lean side.

- The ATTEC trimmer does not deliver a full 3D cutting profile, which is desired for beef striploins. This is largely due to the wide variation of fat thicknesses. To remove close to 60 mm of fat (which has been measured as a possibility in beef), it is necessary to pass the primal at least three times over the cutters of the ATTEC 3D pork loin fat trimmer. Furthermore, beef fat cover requires changes in the angle of the blade, requiring the "piano" type blades to twist as well as move up and down during the cutting process, which is unrealistic.
- Trials with wizard cutters suggest a more realistic approach where cutting action can match the same capabilities achievable by human action in manipulating such a hand tool. Although the cutting line is 2D, the actions to rotate the cutter whilst changing the depth of cut with a motorized attachment can provide a potential solution.
- The capability of an integrated trimming device and an automated positioning system to achieve the process of fat trimming for a uniform fat cover on beef striploin has tested in a specific robotic rig.

Continuation of the project under Stage 2 has already started, which is intended to produce a prototype for standalone operation in an Australian beef plant.

KK Aug 2016