final report

Project code: A.TEC.0082

Prepared by: Sean Starling
Scott Technology Ltd

Date submitted: July 2011

Date published: September 2011

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Automated beef back boning – Conceptual design phase 1B

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government and contributions from the Australian Meat Processor Corporation to support the research and development detailed in this publication.

Abstract

Since 2008, DMRI have been supported by the Australian Meat Processing Corporation and Meat and Livestock Australia to evolve the development of a Beef Striploin deboning machine based on DMRI's knowledge of similar developments in the European Pork Industry. After completing two phases of the project, DMRI have developed a test rig that effectively clamps and 'featherbone ploughs'. The rig incorporates a chine bone saw that effectively cuts the chine bone and additional work is required to determine how best to accurately place the saw cut. Finally a series of rib knives have been developed that have been demonstrated to effectively remove the striploin from the rib bones, albeit with significant operator involvement during the knifing process. Future developments should focus on improving the yield recovery pertaining to the rib knifing process.

Executive summary

History

In 2008 the Australian Meat Processing Corporation (AMPC) Technology Committee, supported by the AMPC Board and Meat and Livestock Australia Ltd (MLA) approved a project to initiate the development of a beef striploin boning machine by the Danish Meat Research Institute (DMRI).

Since 2008 DMRI has undertaken two phases (Phase 1A and 1B) of development and have developed a test rig to clamp, featherbone plough, chine bone saw and rib knives. The test rig has successfully demonstrated clamping and featherbone ploughing. Chine bone sawing was demonstrated to be effective however there are still unknowns with respect to how best to determine where to place the chine bone saw cut. Rib knife development needs additional work.

Phase 1B Outcomes

During Phase 1B (2010/11) DMRI successfully completed two out of five project objectives (clamping and featherbone ploughing). DMRI arguably achieved a third project objective however it is still unknown how best to position the chine bone saw from a meaningful reference point. The chine saw also needs additional consideration on the profile of the saw and the rotation and traversing speed.

One of the remaining two objectives not met was a review and update of the project's finished solution cost benefit analysis to Australian processors. DMRI/Scott have not updated the cost benefit analysis as the yield of the machine is not acceptable and will require additional work and solutions to rectify the problem. An updated cost benefit analysis will take place if the project continues and resolves the yield recovery issue.

Yield Recovery

The fourth project objective was the development of multiple rib knives to remove the striploin from the rib bone set. Although DMRI developed three knives, operating in series, the resulting yield of these knives when working with the rest of the testing rig was not successfully demonstrated within the first four striploins processed. This area/attribute is the projects' most significant detriment to future success.

Applying additional operational procedures such as marking the ribs before processing, applying hooks to the striploin and pulling the striploin as the rib knives traversed and adjusting the profiles of the knives substantially increased the yield recovered.

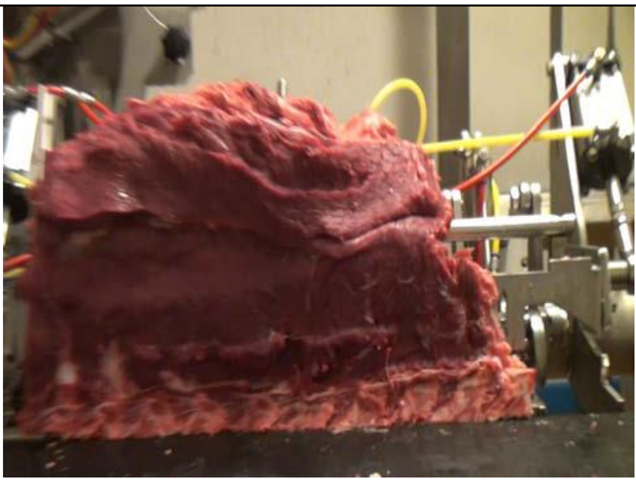
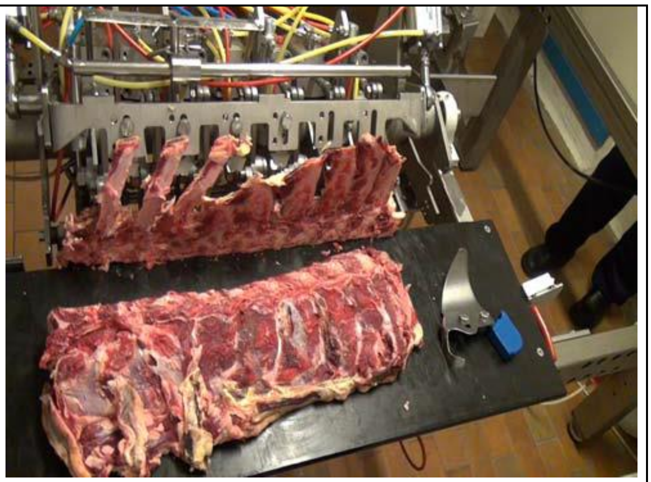
	

Figure 1: Unacceptable yield result	**Figure 2: Acceptable yield result (achieved by applying additional processing aids to the rig)**

Table 1 provides a high level summary of the thirteen striploins processed during the week evaluation at the end of the project. The table depicts whether each area of focus was successful and overall whether the outcomes was successful (based on visual yield).

Table 1: Summary of final week evaluation trials (July 2011)

	Unit Operations					Other Operations				Comments
Striploin	Clamping	Featherbone	Chine Bone	Rib Knife	Outcome	Rib Scribing	Hook Pulling	Mod. Knives	Featherbone Scribing	
1	Orange	Green	Green	Orange	Orange	○	○	○	○	Meat not removed (including intercostal meat) resulted in a yield loss of 1.2 kilograms. Not all of this yield will be recoverable, however at least half of this should have been on the loin.
2	Green	Green	Green	Red	Red	○	○	○	○	The third rib knife cut into the striploin and left a 'flap' of meat that would have to be trimmed off and sold as trim rather than striploin.
3	Green	Green	Green	Red	Red	○	○	○	○	Rib knives jammed and resulted in the loin being removed with a manual knife.
4	Red	Red	Red	Red	Red	○	○	○	○	Loin could not be processed as it was soft-sided and could not be clamped
5	Green	Green	Green	Green	Green	○	Purple	○	○	The use of hooks in the striploin to pull the striploin away from the ribs during the rib knifing process resulted in an acceptable yield.
6	Green	Green	Green	Green	Green	Purple	Purple	○	○	Marking of the ribs and the use of hooks in the striploin to pull the striploin away from the ribs during the rib knifing process resulted in an acceptable yield.
7	Green	Green	Green	Orange	Green	○	Purple	○	○	Marking of the ribs and the use of hooks in the striploin to pull the striploin away from the ribs during the rib knifing process resulted in an acceptable yield.
8	Green	Red	Green	Orange	Green	Purple	○	○	○	'Round' rib bones only where scribed and no striploin hooks were used. An acceptable yield outcome.
9	Green	Green	Green	Green	Green	○	○	Purple	○	New rib knife profiles with not additional operations resulted in an acceptable yield.
10	Green	Green	Green	Green	Green	○	Purple	Purple	○	New rib knife profiles with striploin hooks resulted in an acceptable yield.
11	Orange	N/A	Green	Green	Green	Purple	Purple	Purple	Purple	New rib knife profiles, featherbone and ribs marked and used striploin hooks resulting in an acceptable yield.
12	Orange	N/A	Green	Red	Red	○	○	Purple	Purple	Striploin was too small to be effectively processed in the rig. Size is a limitation with a fixed rig setup.
13	Orange	N/A	Green	Red	Green	Purple	Purple	Purple	Purple	Featherbone and ribs 'heavily' marked, striploin hooks used. Resulted in an acceptable yield except for where two ribs broke.

Development Question

The question now stands…

Is it worth applying the additional operational concepts evaluated to the rig and determine if they provide a 'hands off' solution that results in acceptable yield recovery of each striploin?

Proposed Phase 1C (and beyond)

Industry expert, John Hughes and Sean Starling from Scott Technology both recommend and support such an approach and that the Australian industry further support DMRI, under the direction of Ove Vasvari (DMRI), for a maximum of a three month duration to apply the lessons learnt to the rig and demonstrate the improvements. It is also recommended that the location for product testing be relocated to a beef processing facility close to DMRI to ensure appropriate striploins can be sourced.

Objective		Compliance	Notes	Next Steps
1.	Clamping		Sufficient development undertaken until Phase 2 including automated clamping and simultaneous dynamic spinal alignment.	Revisit in Phase 2
2A.	Featherbone ploughing		Sufficient development undertaken until Phase 2. Acceptable yield recovery.	Revisit in Phase 2
2B.	Chine bone sawing		New saw blade profile/speed required. How deep should cut be made? How will the final machine make this determination?	Revisit in Phase 2
2C.	Striploin rib removal		No acceptable meat recovery rates without consideration other actions being undertaken to assist machine. Significantly and repeatedly/reliably achieving acceptable yield recovery rates when performing this cut is to be the main focus of proposed Phase 1C developments.	Focus of Phase 1C
3.	Updated cost benefit		Not commenced	Complete after proposed Phase 1C but before Phase 2

Table 2: Future Project Phase Focus

Contents

1 Background

In 2008 the Australian Meat Processing Corporation (AMPC) Technology Committee, supported by the AMPC Board and Meat and Livestock Australia Ltd (MLA) approved a project to initiate the development of a beef striploin boning machine by the Danish Meat Research Institute (DMRI).

This support was as of direct result of a previous feasibility study jointly funded by MLA and DMRI (P.PSH.0358), where three operations were identified as having the potential to be automated in a cost effective manner. The beef back boning operation resulted in the highest return.

At that time team members involved in P.PSH.0358 estimated that if the back bone could be boned out automatically, a labour reduction of up to six (6) operational staff could be achieved. At an average labour cost of AUD$70,000 per operator, a machine retailing and installed at AUD$840,000 would result in a two (2) year payback. DMRI believed this target price was realistic.

1.1 Danish Meat Research Institute (DMRI)

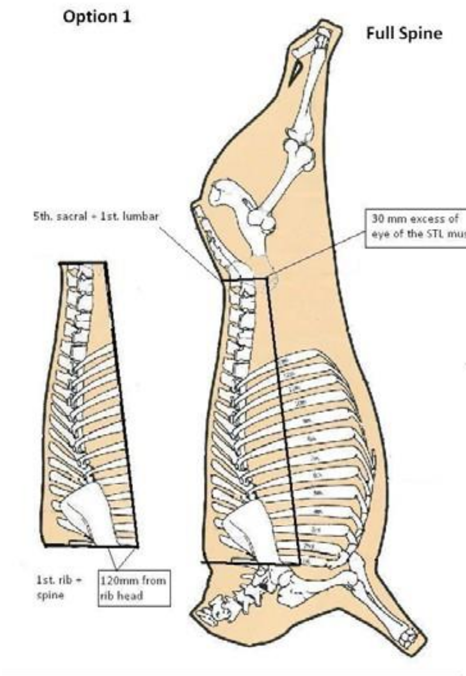
DMRI was selected as the preferred early research and development organisation due to DMRI's successful history in automating both slaughter and de-boning tasks in the pork processing sector in Europe. As such DMRI could leverage on their past experience of successfully automating the de-boning of pork middles, a technology installed and operational in dozens of plants in Europe and commercialised by ATTEC.

Figure 3: DMRI (ATTEC) Automated Pork Middle deboning system.

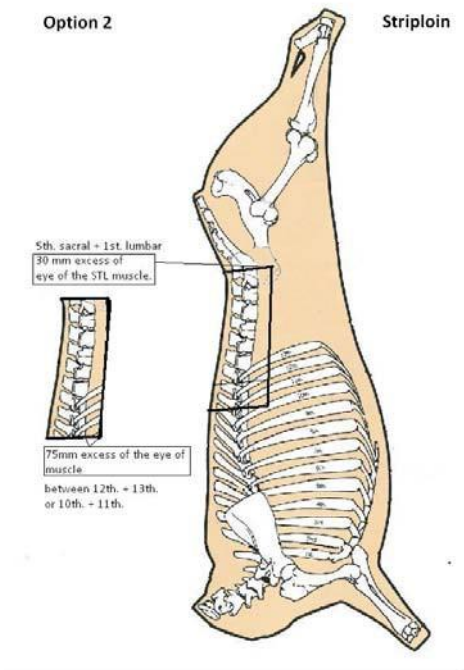
From the outset DMRI made it clear that the full development of an automated system to debone beef backs would span across three (3) to five (5) years and require and investment of at least AUD$2-3 million.

1.2 Which Beef Boning Task to Automate!

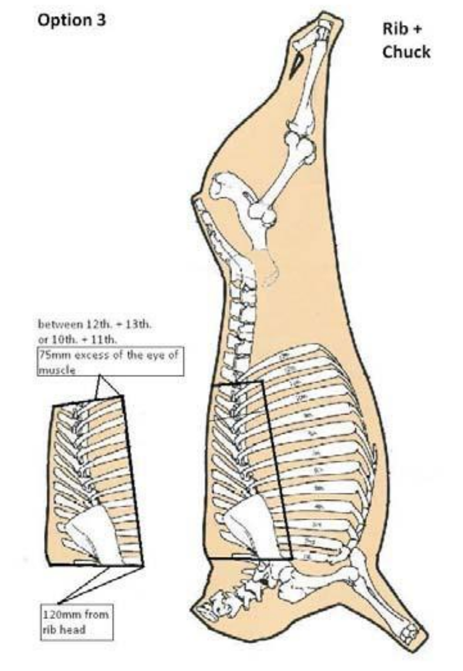
In 2009 and Australian beef working group under the guidance of MLA worked with DMRI to identify four options that could be developed into a project scope.



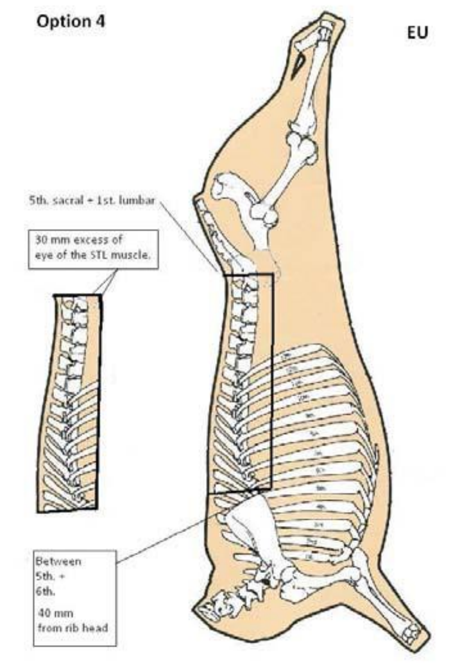
Option 1 – Full Spine



Option 2 - Striploin



Option 3 – Rib and Chuck



Option 4 – EU Specification

Figure 4: Automated Beef Back De-boning project scope options.

After significant deliberation, the Australian beef working group decided to progress with option 2.

1.3 Machine Concept

After taking into consideration operations at Australian beef processing facilities and various recommendations from the Australian beef processing company representatives, DMRI proposed the following concept early in Phase 1.

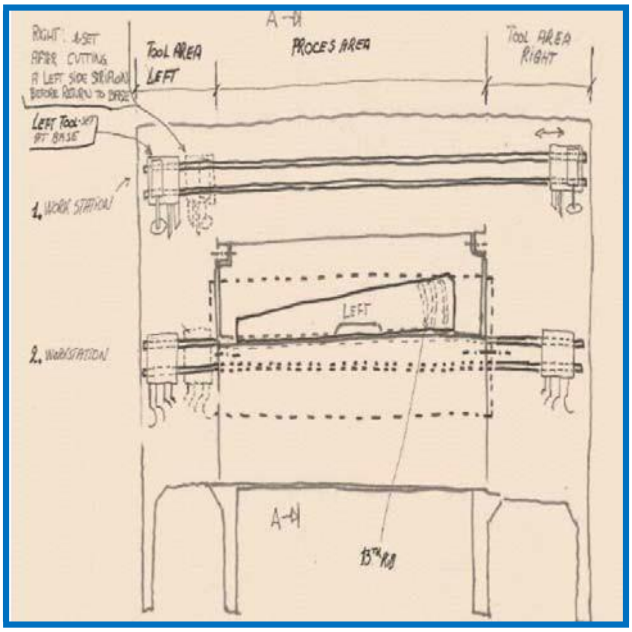


Figure 5: Concept machine (circa 2008) - front View

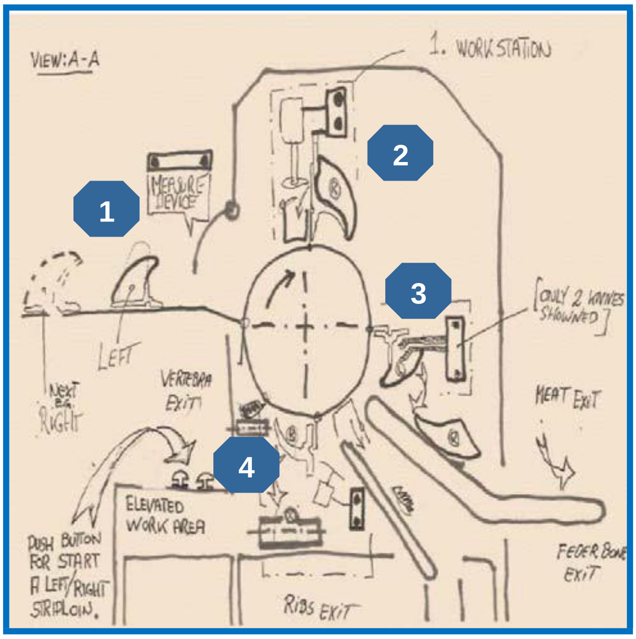


Figure 6: Concept machine (circa 2008) - side view

The concept machine will be manually loaded with left or right striploins. The early thoughts of how the machine might function is as follows:

1. The operator would be presented with alternative right and left loins.

2. The operator might be required to use a measuring ‘device’ that would either automatically configure the machine or require the operator to manually adjust or select a size range. This is to accommodate size variation (Location 1, Figure 6).
3. The operator will hold the loin firm whilst the machine clamping system engaged and fixed the loin to the machine internal turret (Location 1).
4. The turret would rotate 90 degrees and the following two processing cuts would be undertaken (at Location 2):
    a. Featherbone cut (plough)
    b. Chine bone cut (circular saw)
5. The machine turret would rotate 90 degrees (to Location 3) and a series of rib knives would separate the loin into the following three components:
    a. Striploin
    b. Featherbones
    c. Chine and rib bones (as a connected set)

   The Striploin and featherbones would exit at Location 3
6. The machine turret would rotate an additional 90 degrees (to Location 4) and the chine and rib bone set would be ejected from the machine.

1.4 R&D Rig Concept

To reduce the total R&D budget required and in an aim to fast track developments and make modifications technically easier, time efficient and costs effective as R&D leassons where acquired, DRMI built a simple rig that could be used to demonstrate the four mechanical critical risk components:

1. Clamping
2. Featherbone plough
3. Chine bone cut
4. Rib knifing

At the conclusion of the Phase 1A project (circa 2009) a rig had been developed that provided a rudimentary demonstration of clamping, featherbone ploughing and chine bone cutting. Clamping was manually engaged and the featherbone plough and chine bone saw where manually replaced with each other depending upon which was required at the time of traversing.

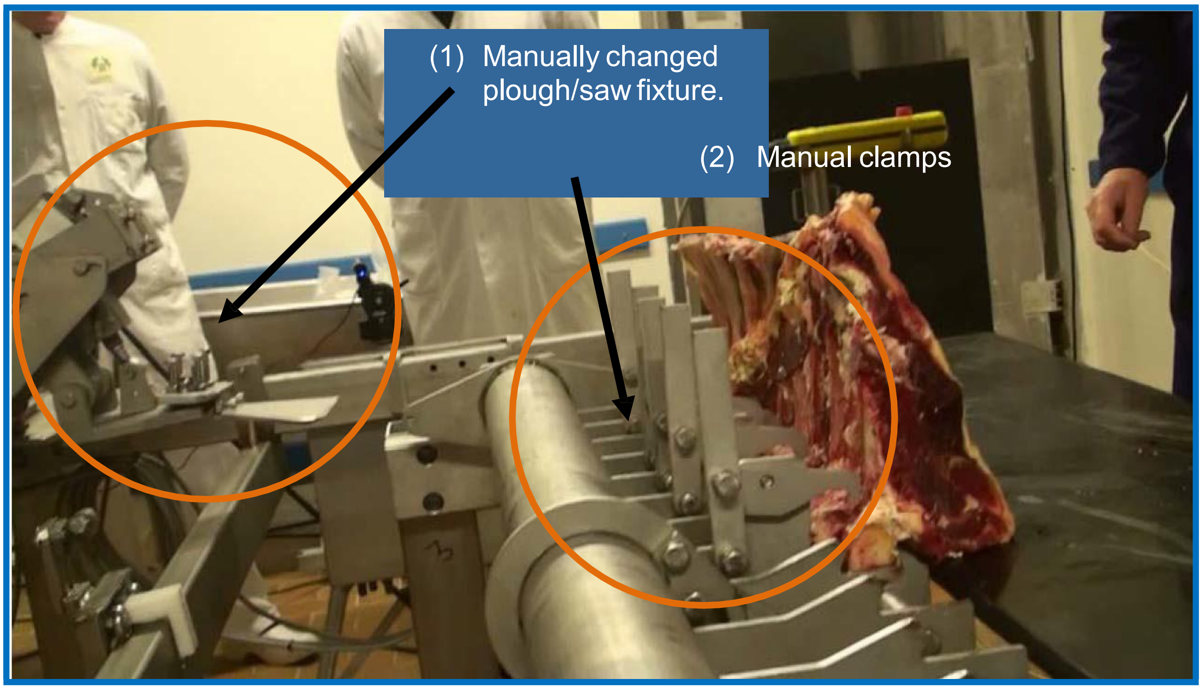


Figure 7: Phase 1A R&D Test Rig (circa 2009) → Clamping component depicted only.

A significant part of the investment of the Phase 1b project was to:

1. Replace the manual clamping with automatic clamping, with the added inclusion of an automated spinal column straightening device whilst simultaneously clamping.
2. Upgrade the cutting tool station to enable a quick (albeit still manual) change between featherbone (i.e. plough), chine bone (i.e. circular saw) and striploin removal tools (i.e. rib knives).

Of significant importance for the reader is to understand and acknowledge that the purpose of the rig was to develop, test and demonstrate the clamping and cutting end-effectors:

1. Clamping
2. Featherbone plough
3. Chine bone cut
4. Rib knifing

And not to demonstrate how the turret concept (refer Figure 6) would work in the final machine. Hence the trial videos depict the cutting end-effectors being rotated and not the striploin, as is proposed in the final solution (refer Figure 6).

1.5 Phase 1A outcomes and recommendations

Phase 1A developed the test rig depicted in Figure 5. The focus of Phase 1A was:

1. the profile of the proposed clamping design,
2. the featherbone plough, and
3. chine bone saw

DMRI successfully demonstrated the ability to clamp a loin and hold it rigidly whilst being processed/worked on by various end effectors. Although it was acknowledged that for the final automated solution a ‘dynamic alignment’ mechanism would be required that would simultaneously straighten the loin whilst it was being clamped (undertaken during Phase 1B). The ‘beef’ clamp design was a significant detour from the ‘pork’ clamp design and as such additional work in the area of clamping would be required (undertaken during Phase 1B).

DMRI successfully demonstrated the ability of the featherbone plough end effector to separate the featherbone from the loin. Although it was acknowledged by the Australian review team and DMRI that additional work was required to determine the best blade/plough design and traversing alignment/pressure application (undertaken during Phase 1B).

DMRI successfully demonstrated the ability for the chine bone to be cut with a circular saw.

In total during Phase 1A DMRI processed approximately fifty (50) strip loins.

Note: Under Phase 1A there was no development work, and hence demonstration, of the rib knives. This was to be a focus of future stages (undertaken during Phase 1B).

2 Project objectives

Taken from the DMRI contract……

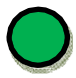
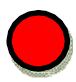
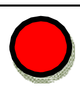
Phase 1B was aimed at optimising the fixation/grabbing of the back by use of the work bench clamping model on several backs. Phase 1B will develop method and tools to cut across bones in a stepwise movement. Furthermore the machine price, NPV and development cost of remaining phases will be updated. Main objectives of this phase are:

- To optimise, the grabbing of the back spine in the work bench model [Objective 1].
- To develop the complete cutting and sawing patterns on the back to allow removal of all bones [Objective 2].
- Update of cost benefit [Objective 3]

The work bench model [from Phase 1A] will be used as part of the project, and will constitute the tool for researching clamping and cutting methodology.

Table 3 depicts the status of successful objective compliance at the conclusion of Phase 1B.

Table 3: Phase 1B Objective Compliance Report Card

Objective		Compliance	Notes	Next Steps
1.	Clamping		Sufficient development undertaken until Phase 2 including automated clamping and simultaneous dynamic spinal alignment.	Revisit in Phase 2
2A.	Featherbone ploughing		Sufficient development undertaken until Phase 2. Acceptable yield recovery.	Revisit in Phase 2
2B.	Chine bone sawing		New saw blade profile/speed required. How deep should cut be made? How will the final machine make this determination?	Revisit in Phase 2
2C.	Striploin rib removal		No acceptable meat recovery rates without considering other actions being undertaken to assist machine. Significantly and repeatedly/reliably achieving acceptable yield recovery rates when performing this cut is to be the main focus of proposed Phase 1C developments.	Focus of Phase 1C
3.	Updated cost benefit		Not commenced	Complete after proposed Phase 1C but before Phase 2

3 Methodology

Phase 1B was predominantly an engineering research and development phase as compared to a laboratory science research and development phase.

As such the methodology was to:

Test Rig

1. Upgrade the manual clamping system to automatically clamp the loin whilst simultaneously applying/deploying a dynamic spinal straightening mechanism.
2. Modify the test rig frame to enable a three (3) point multiple end effector head to be developed, installed and operated without significant vibration of rig/loin misalignment/movement.
3. Development of a three point multiple end effector head.
4. Fixation of existing featherbone plough and chine bone circular saw to the three point multiple end effector head.
5. Development of the required numbers of rib knives and fixation to the three point multiple end effector head.

Meat Processing

1. Process loins on the test rig and compare against an acceptable standard as developed by John Hughes and Sean Starling (see below).
2. Modify rig and end effectors to take into account learnings and repeat meat testing.

3.1 Acceptable Loin Yield Recovery Standard (also refer Appendix A)

To ensure that DMRI had a standard to compare their trial results against that would be acceptable to the Australian industry, John Hughes and Sean Starling undertook benchmarking activities and develop a report that stipulated the required standards. Refer Appendix A for the full report.

4 Results and discussion

The following results are presented grouped around the methodology areas of Phase 1B. Each striploin tested has its own detailed individual analysis followed by a high level summary of all trials for cross comparison.

4.1 Test Rig – Overview

Claus provides a narrative on how the test rig functions in the video titled: ”Claus explains the test rig (1080)”. (Duration = 01:23). A step by step operation is depicted in Appendix B.

Figure 8: Test rig (located at DMRI workshop)

4.2 Test Rig – System Clamping Upgrade to Automatic Alignment and Clamping

DMRI successfully developed and enhanced the Phase 1A test rig to align the striploin spinal cavity whilst the spinal cavity clamps progressively deployed.

The automated alignment and clamping system (note: not automated loading) comprises of three discrete components:

1. Top clamp.
2. Spinal cavity guide that traverses during chine bone clamping.
3. Four (4) individually activated spinal cavity clamps (vertebrae).
4. Seven (7) individually activated chine bone clamps.

Figures 10 to 21 inclusive demonstrate the automated alignment and clamping in operation (as stills) and video titled: “Dry run of the spinal clamping mechanism (1080).mpg” shows the clamping dry cycling.

Figure 9: Rig in 'ready to load' mode.

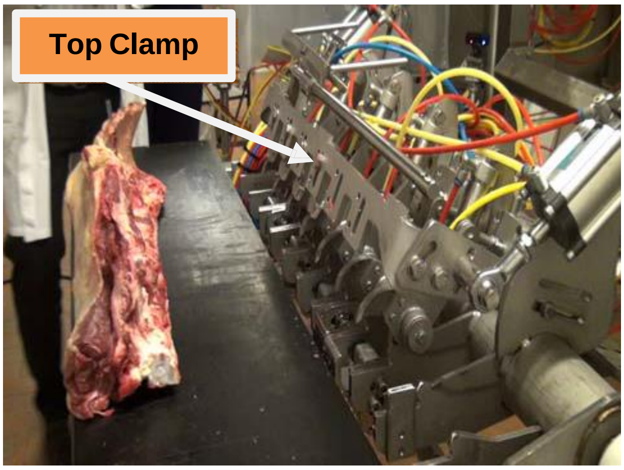


Figure 10: Top clamp commences clamping traverse.

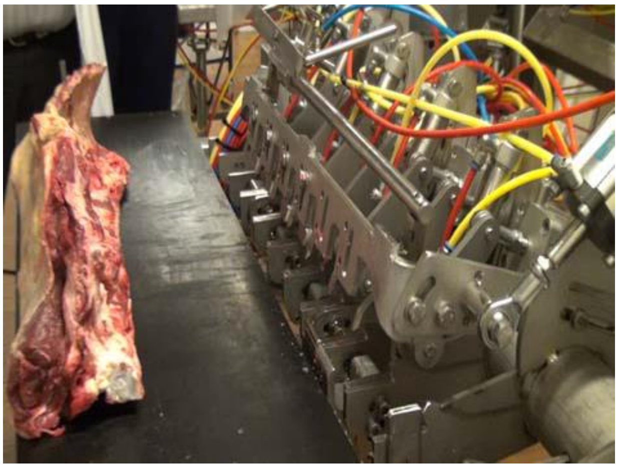


Figure 11: Top clamp continues clamping traverse.

Figure 12: Top clamp continues clamping traverse.

Figure 13: Top clamp completes clamping traverse.

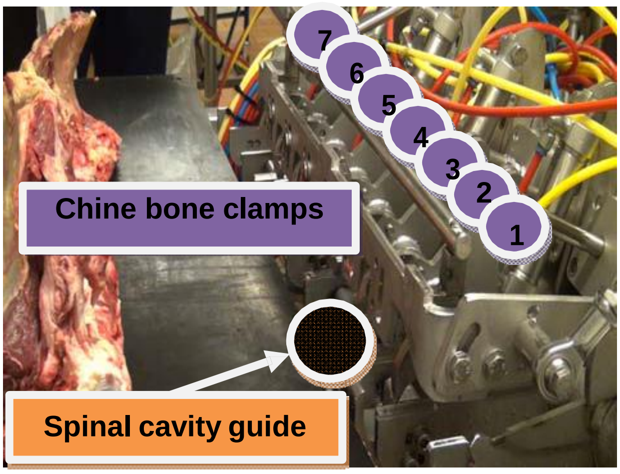


Figure 14: Spinal cavity guide commences traverse and chine bone clamp 1 closes.

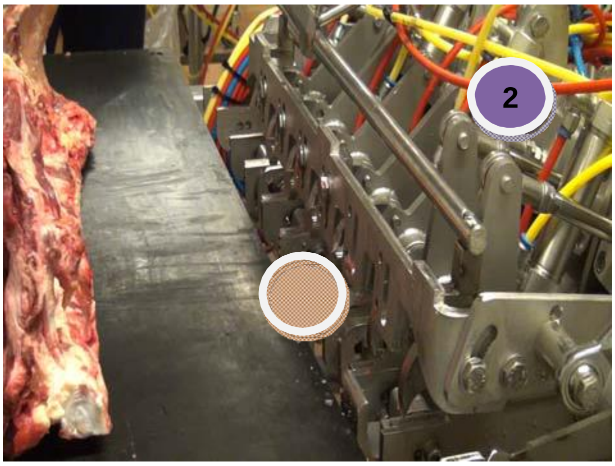


Figure 15: chine bone clamp 2 closes

Figure 16: chine bone clamp 3 closes

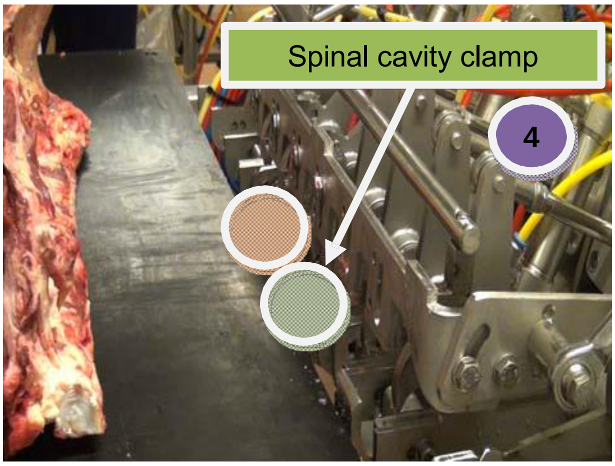


Figure 17: chine bone clamp 4 closes and spinal cavity clamp 2 engages

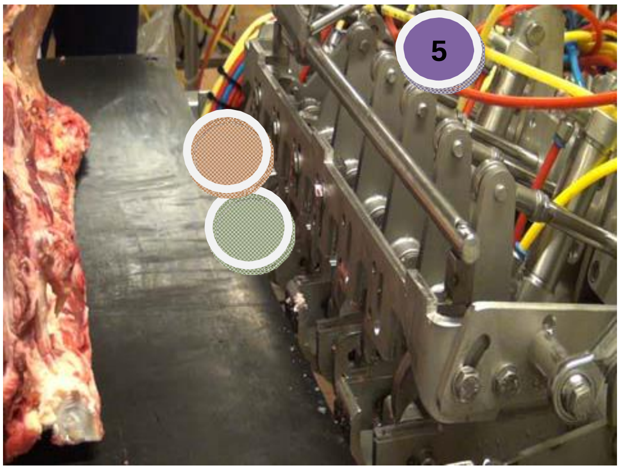


Figure 18: chine bone clamp 5 closes and spinal cavity clamp 3 engages

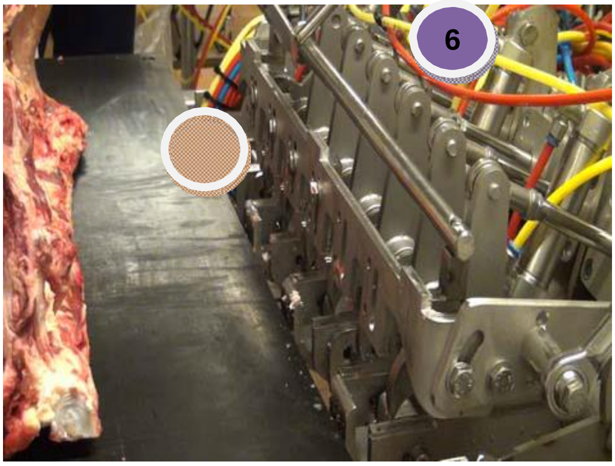


Figure 19: chine bone clamp 6 closes

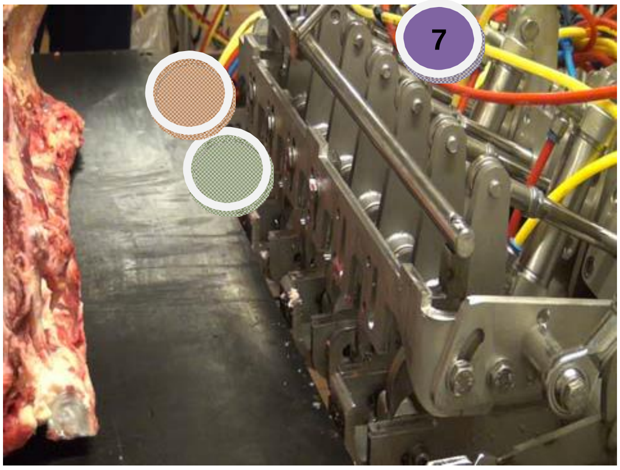


Figure 20: chine bone clamp 7 closes and spinal cavity clamp 4 engages

General comments:

1. The clamping arrangement has the potential to be an issue on soft sided animals, i.e. the system with the current configuration cannot clamp a soft-sided striploin. This is an area that will need to be monitored in future phases.
2. The system requires an operator to firmly hold and apply pressure against the striploin whilst the automated alignment and clamping process is executed. This was always intended to be the case during phase 1B and the conceptual first production prototype (Refer: Figure 6).

4.3 Test Rig – Development of a 3-Point end effector head

DMRI successfully developed a multi-purpose 3-point (Feather bone plough, chine bone saw, rib knives) end effector.

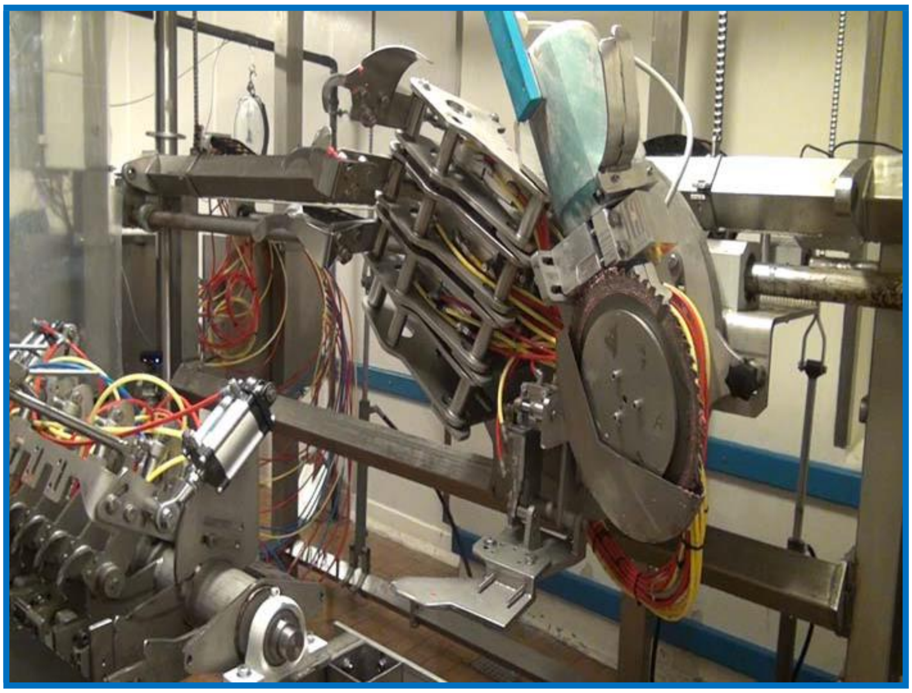


Figure 21: Three point cutting end effector head

4.4 Test Rig – Rib Knives

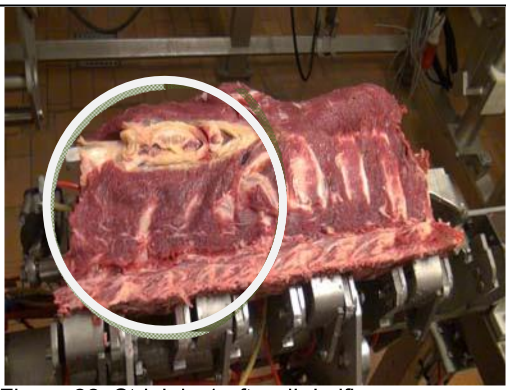
After determining that the rib knife profiles could be improved following processing the 8th striploin, the project team made profile adjustment to knives two and three. The newly profiled knives where then traversed across previously cleared rib sets to ensure an average profile was achieved.

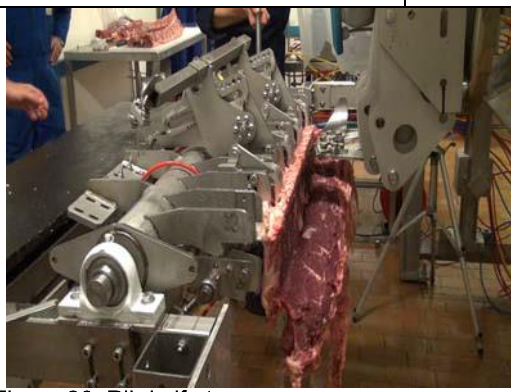
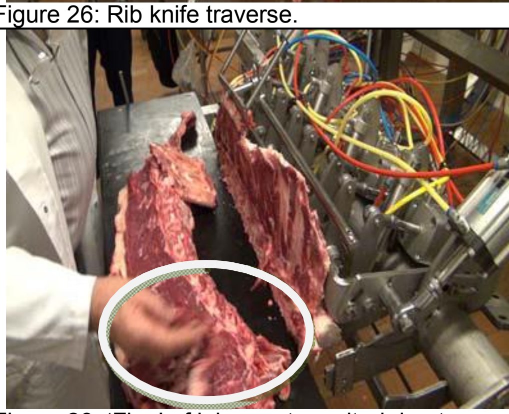
Video	• 2011-07-07 - Knife Adjustments (1440).mpg [High Resolution] • 2011-07-07 - Knife Adjustments (1280).mpg [Medium Resolution] • 2011-07-07 - Knife Adjustments (720).mpg [Low Resolution]

Striploins 9 to 13 inclusive where processes with the new rib knife profile configurations.

4.5 Meat Processing – Evaluated against "Australian" Standard

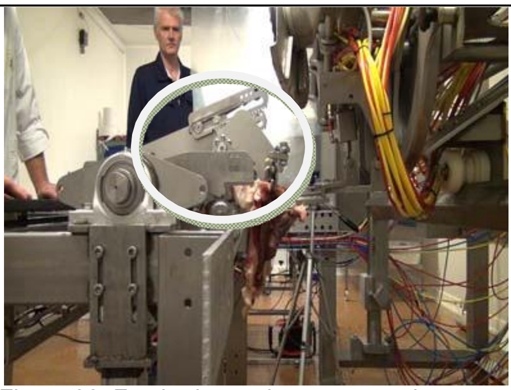
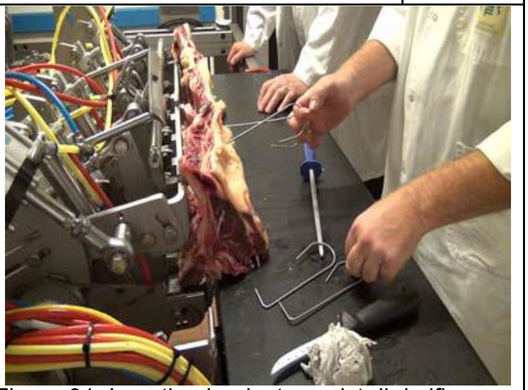
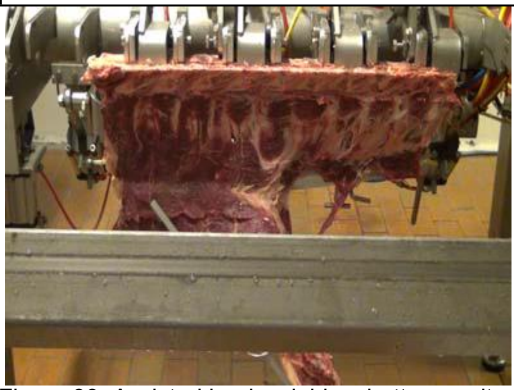
The following summary provides an insight into the striploins processed over a four day period during the first week of July 2011 whilst John Hughes and Sean Starling were in attendance at the DMRI test facility in Denmark. A colour light coded system has been used to assist the reader in determining the success of each foci. Red is a failure, Green is a success and orange indicates a failure although a possibility of becoming a success.

5th July 2011	Striploin 1	
Clamping	Not effective first time (last clamp needed realignment)	
Featherbone plough	Effective	
Chine bone sawing	Effective	
Rib Knifing	Traversed without jamming, however sufficient amount of yield was not recovered. May have been an alignment problem between the 'flat' and the 'round' rib bones.	
Other actions	None	
Outcome	Yield showed promise but not acceptable.	
	 Figure 22: Striploin 1 after rib knifing process. Note loss of yield on left hand side of photo.	 Figure 23: Striploin 1 after being knifed from ribs
	 Figure 24: Removed meat from intercostal. Note: some of this will never be recovered with an optimised machine.	
Video	• 2011-07-05 Striploin 1 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 1 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 1 (edited) (720).mpg [Low Resolution]	

5th July 2011	Striploin 2	
Clamping	Effective	
Featherbone plough	Effective	
Chine bone sawing	Effective	
Rib Knifing	Traversed without jamming. The yield recovery was better than observed in Striploin 1 however still not at the required standard. The issue for Striploin 2 was the at the commencement of the rib knives, the rib knives did not enter sufficiently close enough to the ribs, hence resulting in lost yield.	
Other actions	None	
Outcome	Yield improved over Striploin 1 but still not acceptable.	
	 Figure 25: Effective chine bone saw cut..  Figure 26: Rib knife traverse.	
	 Figure 27: Yield left on the bones.  Figure 28: 'Flap' of loin meat resulted due to poor rib knife cut (believe rib knife 3 caused the problem). Additional yield loss.	
Video	• 2011-07-05 Striploin 2 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 2 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 2 (edited) (720).mpg [Low Resolution]	

5th July 2011	Striploin 3	
Clamping	Effective	
Featherbone plough	Effective	
Chine bone sawing	Effective	
Rib Knifing	Rib knives jammed on leading ribs and stalled the machine. Two attempts are applying the ribs knives where required. Finally the striploin was removed with a hand knife.	
Other actions	None	
Outcome	Loin was knifed off as a result of the rib knives jamming.	
	 Figure 29: Chine bone plough top guide engaged.	
Video	• 2011-07-05 Striploin 3 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 3 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 3 (edited) (720).mpg [Low Resolution]	

5th July 2011	Striploin 4	
Clamping	Not effective, the striploin was soft-sided and could not be clamped.	
Featherbone plough	N/A	
Chine bone sawing	N/A	
Rib Knifing	N/A	
Other actions	none	
Outcome	Loin could not be processed.	
Video	• 2011-07-05 Striploin 4 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 4 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 4 (edited) (720).mpg [Low Resolution]	

7th July 2011	Striploin 5	
Clamping	Effective	
Featherbone plough	N/A	
Chine bone sawing	N/A	
Rib Knifing	N/A	
Other actions	Used hooks in the striploin muscle to pull the meat away from the ribs as the rib knives undertook their traverse.	
Outcome	Yield recovery was acceptable with the use of the hooks.	
	 Figure 30: Featherbone clamp engaged.	 Figure 31: Inserting hooks to assist rib knifing process.
	 Figure 32: Assisted hooks yields a better result compared with the previous three striploins.	 Figure 33: Assisted hooks yields a better result compared with the previous three striploins.
Video	• 2011-07-05 Striploin 5 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 5 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 5 (edited) (720).mpg [Low Resolution]	

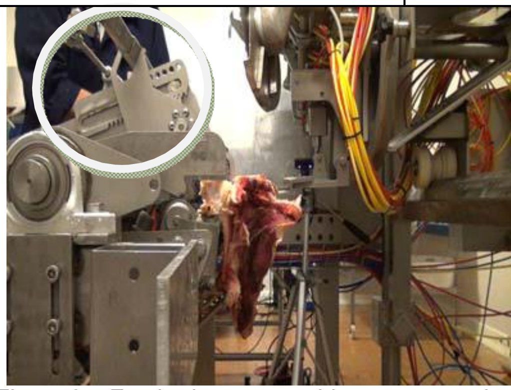
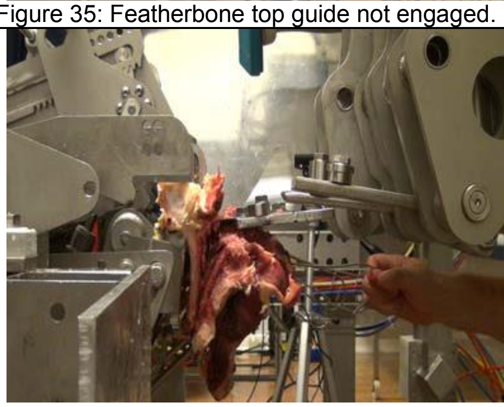
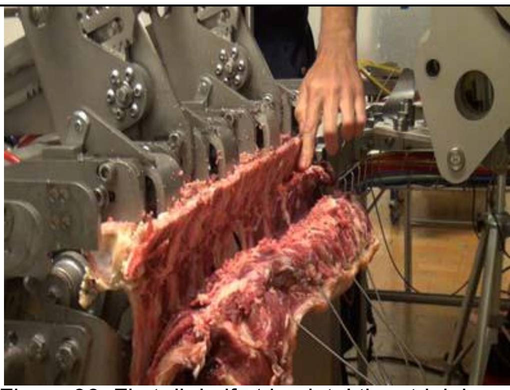
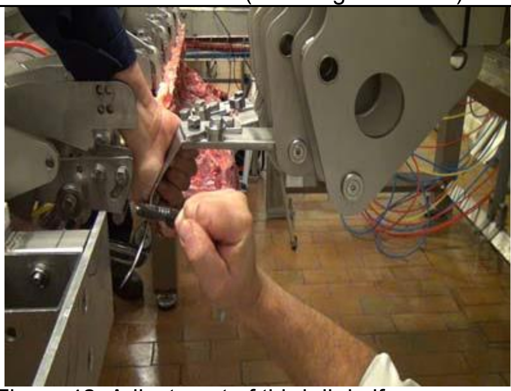
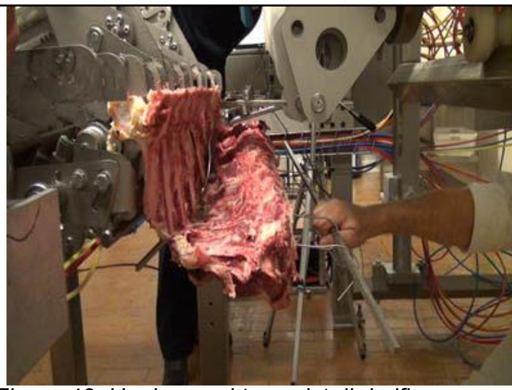
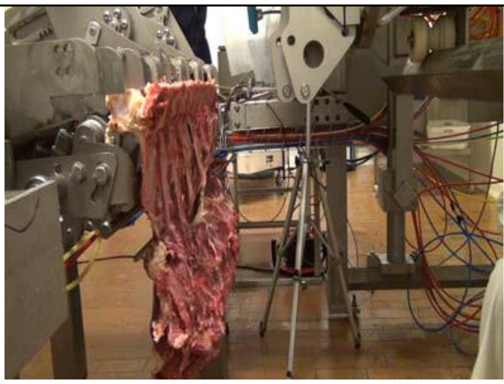
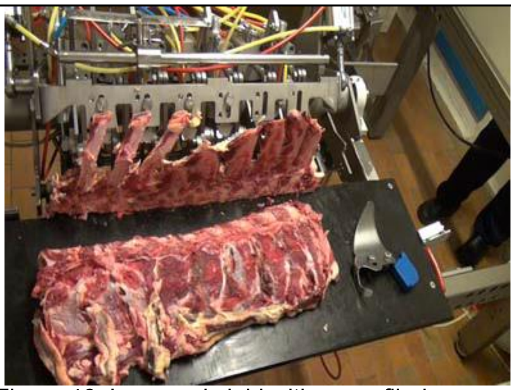
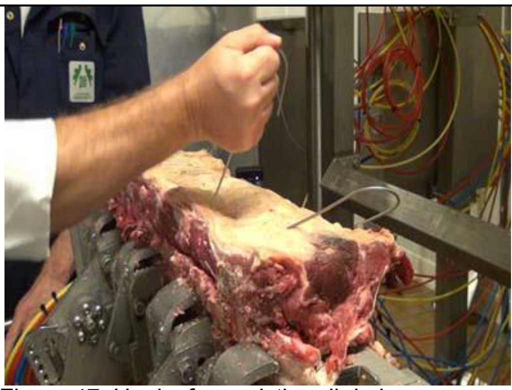
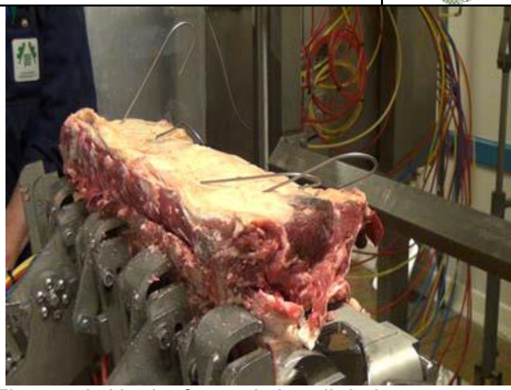
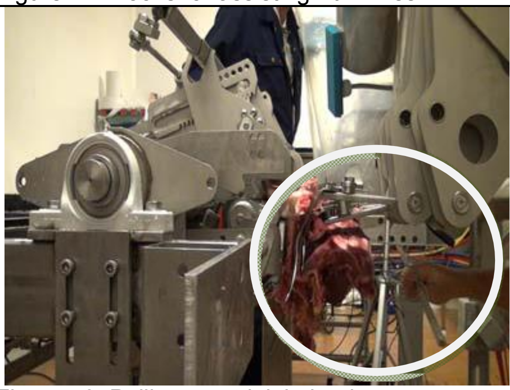
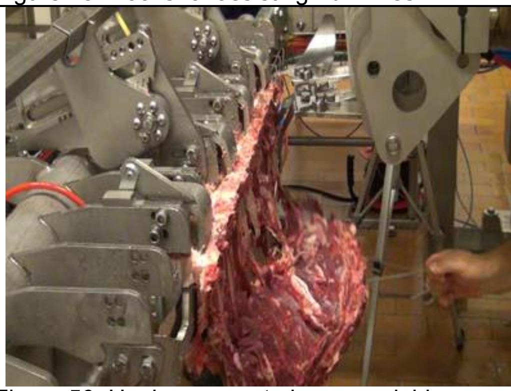
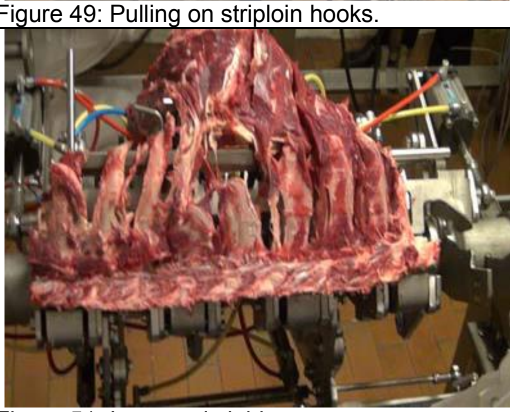
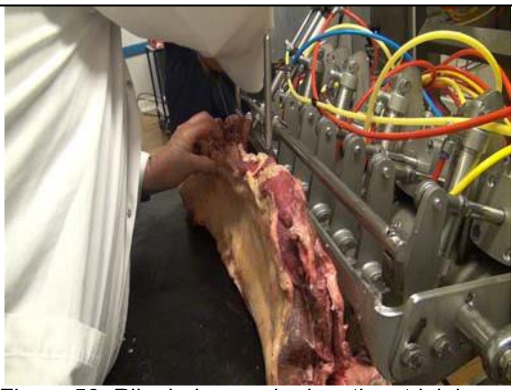
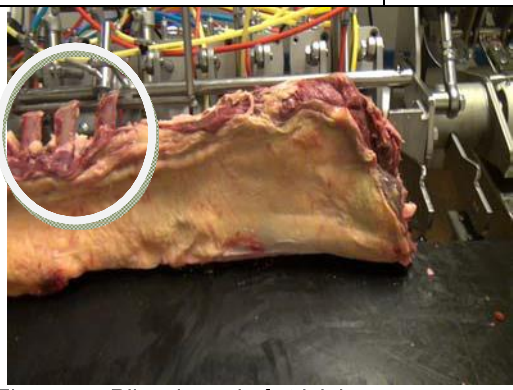
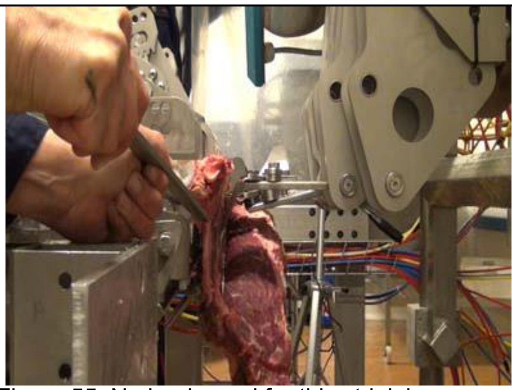
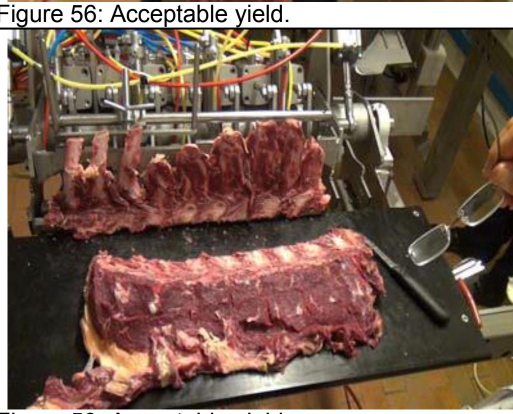
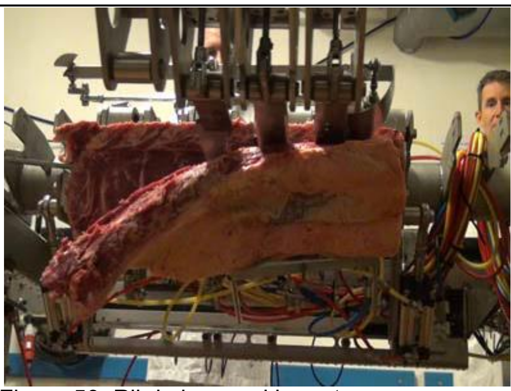
7th July 2011	Striploin 6	
Clamping	Effective	
Featherbone plough	N/A	
Chine bone sawing	The chine bone saw was positioned closer to the jig. Hence the chine was cut closer to the spinal cavity for Striploin 6 – 13 inclusive.	
Rib Knifing	N/A	
Other actions	Ribs where scribed on either side before loading the loin into the rig. Used hooks in the striploin muscle to pull the meat away from the ribs as the rib knives undertook their traverse.	
Outcome	Yield recovery was acceptable with the use of the hooks.	
	 Figure 34: Scribing/Marking of ribs	 Figure 35: Featherbone top guide not engaged.
	 Figure 36: First rib knife only used. Second and third knife removed.	 Figure 37: First rib knife only used. Second and third knife removed.
	 Figure 38: First rib knife 'dug into' the striploin meat and reduced yield (indicated by finger)	 Figure 39: Second pass with second rib knife reintroduced into the rig.

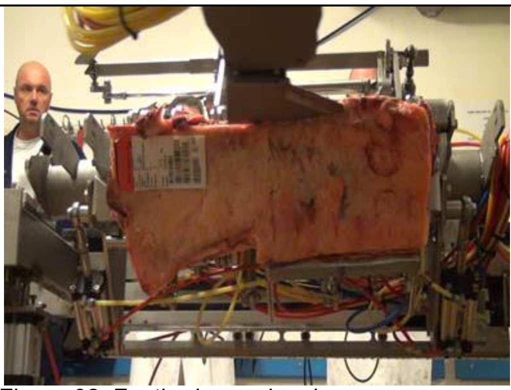
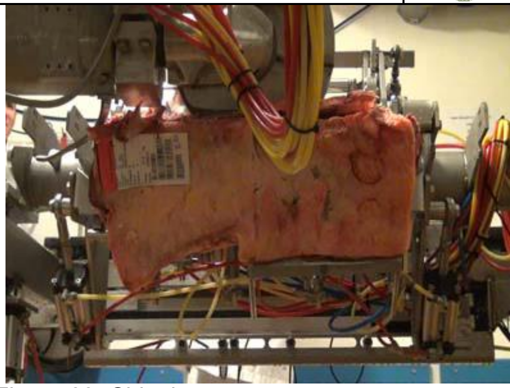
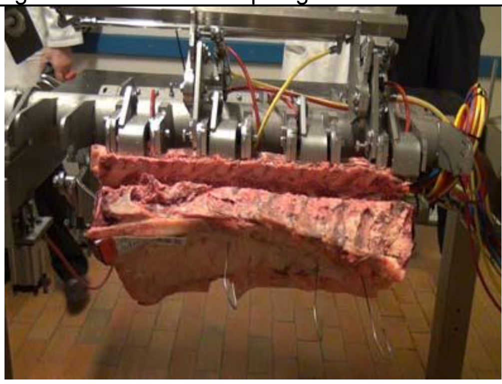
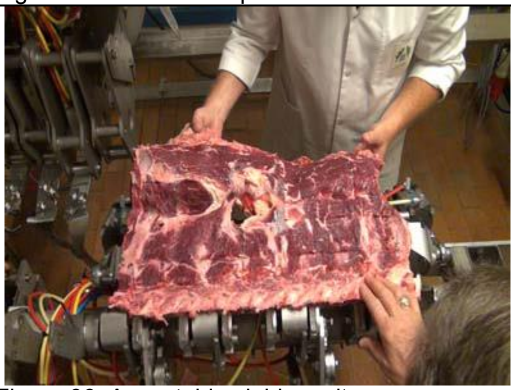
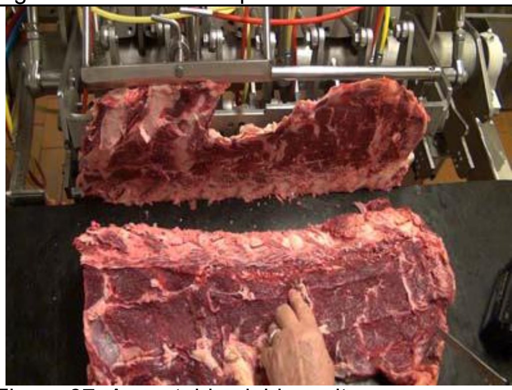
	 Figure 40: Identification that third rib knife profile was not suitable (refer finger location).	 Figure 41: Adjustment of third rib knife.
	 Figure 42: Adjustment of third rib knife.	 Figure 43: Hooks used to assist rib knifing. Traverse with newly profiled knives.
	 Figure 44: Improved yield with re-profiled knives.	 Figure 45: Improved yield with re-profiled knives.
	 Figure 46: Improved yield with re-profiled knives.	
Video	• 2011-07-05 Striploin 6 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 6 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 6 (edited) (720).mpg [Low Resolution]	

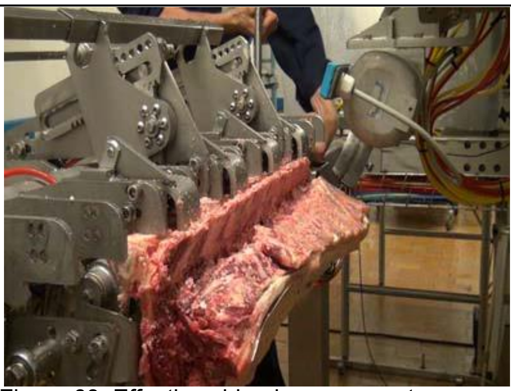
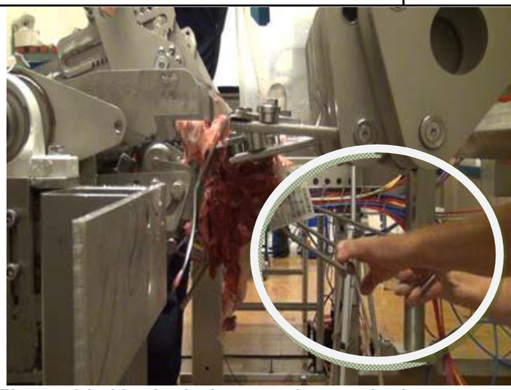
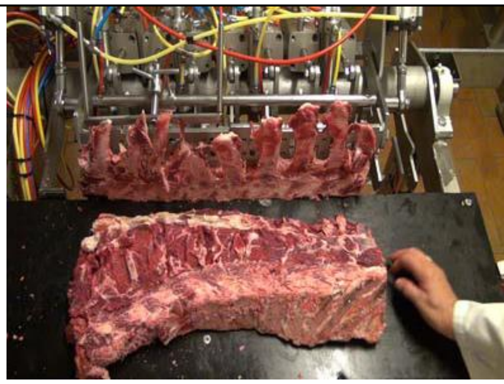
7th July 2011	Striploin 7	
Clamping	Effective	
Featherbone plough	Effective	
Chine bone sawing	Effective	
Rib Knifing	Commenced the knifing process without the lead guide and the knives jammed on the rib bones. The second attempt was successful.	
Other actions	'Round' rib bones where scribed. Used hooks in the striploin muscle to pull the meat away from the ribs as the rib knives undertook their traverse.	
Outcome	Yield recovery was acceptable with the use of the hooks.	
	 Figure 47: Hooks for assisting rib knives.	 Figure 48: Hooks for assisting rib knives.
	 Figure 49: Pulling on striploin hooks.	 Figure 50: Hooks appear to improve yield.
	 Figure 51: Improved yield.	 Figure 52: Improved yield.
Video	• 2011-07-05 Striploin 7 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 7 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 7 (edited) (720).mpg [Low Resolution]	

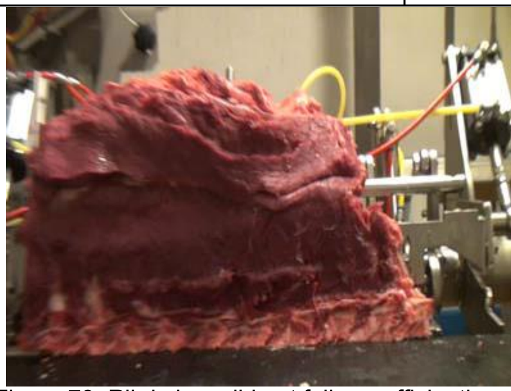
7th July 2011	Striploin 8	
Clamping	Effective	
Featherbone plough	Not effective – the featherbone plough guide was not engaged as a trial and the plough passed along the 'top' of the featherbones.	
Chine bone sawing	Effective	
Rib Knifing	Commenced the knifing process without the lead guide and the knives jammed on the rib bones.	
Other actions	'Round' rib bones only where scribed for a distance of 30-50mm only. Previously the ribs were scribed along the full length.	
Outcome	Yield recovery was acceptable.	
	 Figure 53: Ribs being marked on the striploin sde.	 Figure 54: Ribs cleared of striploin
	 Figure 55: No hook used for this striploin.	 Figure 56: Acceptable yield.
	 Figure 57: Acceptable yield.	 Figure 58: Acceptable yield.
Video	• 2011-07-05 Striploin 8 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 8 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 8 (edited) (720).mpg [Low Resolution]	

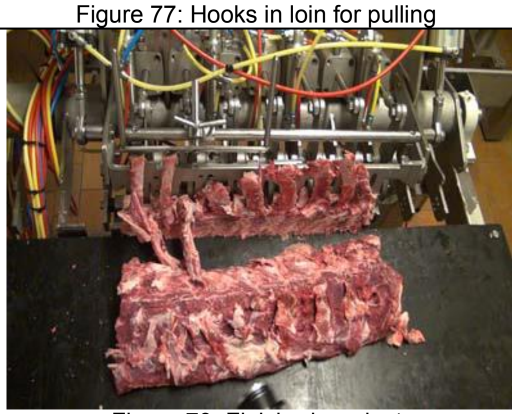
Note: After Striploin 8 was processes, modifications to the profile of rib knives 2 and 3 was undertaken. The knives where re-installed and 'passed over' previous rib sets to ensure the profile was a closer fit on average to the rib profile. Refer video: 2011-07-07 - Knife Adjustments (1440), for alignment testing.

8th July 2011	Striploin 9	
Clamping	Effective	
Featherbone plough	Effective – the featherbone plough guide was not engaged as a trial and the plough passed underneath the featherbones as required. Note this was different than the previous striploin, striploin #8.	
Chine bone sawing	Effective	
Rib Knifing	Effective with newly profiled 2nd and 3rd knives.	
Other actions	None	
Outcome	Yield recovery was acceptable.	
	 Figure 59: Rib knives making a traverse.	 Figure 60: Rib knives finished their traverse.
	 Figure 61: Acceptable yield recovery.	
Video	• 2011-07-05 Striploin 9 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 9 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 9 (edited) (720).mpg [Low Resolution]	

8th July 2011	Striploin 10	
Clamping	Effective	
Featherbone plough	Effective	
Chine bone sawing	Effective	
Rib Knifing	Effective with newly profiled 2nd and 3rd knives.	
Other actions	Used hooks in the striploin muscle to pull the meat away from the ribs as the rib knives undertook their traverse.	
Outcome	Yield recovery was acceptable.	
	 Figure 62: Featherbone plough.	 Figure 63: Chinebone saw
	 Figure 64: Hooks in striploin to assist rib knives.	 Figure 65: Hooks in striploin to assist rib knives
	 Figure 66: Acceptable yield result.	 Figure 67: Acceptable yield result.
Video	• 2011-07-05 Striploin 10 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 10 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 10 (edited) (720).mpg [Low Resolution]	

8th July 2011	Striploin 11	
Clamping	Last location lug needed to be realigned.	
Featherbone plough	Not used due to marking with a knife.	N/A
Chine bone sawing	Effective	
Rib Knifing	Effective with newly profiled 2nd and 3rd knives.	
Other actions	Featherbone was marked with a knife. Ribs/Intercostals were marked. Used hooks in the striploin muscle to pull the meat away from the ribs as the rib knives undertook their traverse.	
Outcome	Yield recovery was acceptable including full intercostal recovery.	
	 Figure 68: Effective chine bone saw cut..	 Figure 69: Hooks being used to assist in striploin removal as rib knives perform their traverse.
	 Figure 70: Hooks being used to assist in striploin removal as rib knives perform their traverse.	 Figure 71: Excellent yield result.
Video	• 2011-07-05 Striploin 11 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 11 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 11 (edited) (720).mpg [Low Resolution]	

8th July 2011	Striploin 12	
Clamping	Last location lug needed to be realigned.	
Featherbone plough	Not used due marking with a knife.	N/A
Chine bone sawing	Effective	
Rib Knifing	Not effective. The striploin was of too small a size.	
Other actions	Featherbone marked with a knife.	
Outcome	Yield was not acceptable with the	
	 Figure 72: Last spinal column clamp being readjusted after unsuccessful clamping operation.  Figure 73: Rib knives did not follow sufficiently close to the ribs and significant yield lost.	
Video	• 2011-07-05 Striploin 12 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 12 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 12 (edited) (720).mpg [Low Resolution]	

8th July 2011	Striploin 13	
Clamping	Last location lug needed to be realigned.	
Featherbone plough	Not used due marking with a knife.	N/A
Chine bone sawing	Acceptable	
Rib Knifing	Acceptable except for where two ribs broke and intercostals were not recovered.	
Other actions	Featherbone marked. All ribs ‘heavily’ marked. Used hooks in the striploin muscle to pull the meat away from the ribs as the rib knives undertook their traverse.	
Outcome	Striploin was a smaller piece relatively when compared with other striploins processed during the week. The yield recovery was acceptable except for two intercostals which were not recovered due to the rib bones breaking during the knifing process.	
	 Figure 74: Extensive rib marking	 Figure 75: Extensive rib marking
	 Figure 76: Extensive featherbone marking.	 Figure 77: Hooks in loin for pulling
	 Figure 78: Hooks in loin for pulling	 Figure 79: Finished product
Video	• 2011-07-05 Striploin 13 (edited) (1440).mpg [High Resolution] • 2011-07-05 Striploin 13 (edited) (1280).mpg [Medium Resolution] • 2011-07-05 Striploin 13 (edited) (720).mpg [Low Resolution]	

4.6 Results Summary

Table 4: High level summary of all loins processed.

	Unit Operations					Other Operations				Comments
Striploin	Clamping	Featherbone	Chine Bone	Rib Knife	Outcome	Rib Scribing	Hook Pulling	Mod. Knives	Featherbone Scribing	
1	🟠	🟢	🟢	🟠	🟠	⚪	⚪	⚪	⚪	Meat not removed (including intercostal meat) resulted in a yield loss of 1.2 kilograms. Not all of this yield will be recoverable, however at least half of this should have been on the loin.
2	🟢	🟢	🟢	🔴	🔴	⚪	⚪	⚪	⚪	The third rib knife cut into the striploin and left a 'flap' of meat that would have to be trimmed off and sold as trim rather than striploin.
3	🟢	🟢	🟢	🔴	🔴	⚪	⚪	⚪	⚪	Rib knives jammed and resulted in the loin being removed with a manual knife.
4	🔴	🔴	🔴	🔴	🔴	⚪	⚪	⚪	⚪	Loin could not be processed as it was soft-sided and could not be clamped
5	🟢	🟢	🟢	🟢	🟢	⚪	🟣	⚪	⚪	The use of hooks in the striploin to pull the striploin away from the ribs during the rib knifing process resulted in an acceptable yield.
6	🟢	🟢	🟢	🟢	🟢	🟣	🟣	⚪	⚪	Marking of the ribs and the use of hooks in the striploin to pull the striploin away from the ribs during the rib knifing process resulted in an acceptable yield.
7	🟢	🟢	🟢	🟠	🟢	⚪	🟣	⚪	⚪	Marking of the ribs and the use of hooks in the striploin to pull the striploin away from the ribs during the rib knifing process resulted in an acceptable yield.
8	🟢	🔴	🟢	🟠	🟢	🟣	⚪	⚪	⚪	'Round' rib bones only where scribed and no striploin hooks were used. An acceptable yield outcome.
9	🟢	🟢	🟢	🟢	🟢	⚪	⚪	🟣	⚪	New rib knife profiles with not additional operations resulted in an acceptable yield.
10	🟢	🟢	🟢	🟢	🟢	⚪	🟣	🟣	⚪	New rib knife profiles with striploin hooks resulted in an acceptable yield.
11	🟠	N/A	🟢	🟢	🟢	🟣	🟣	🟣	🟣	New rib knife profiles, featherbone and ribs marked and used striploin hooks resulting in an acceptable yield.
12	🟠	N/A	🟢	🔴	🔴	⚪	⚪	🟣	🟣	Striploin was too small to be effectively processed in the rig. Size is a limitation with a fixed rig setup.
13	🟠	N/A	🟢	🔴	🟢	🟣	🟣	🟣	🟣	Featherbone and ribs 'heavily' marked, striploin hooks used. Resulted in an acceptable yield except for where two ribs broke.

4.7 Discussion

4.7.1 Project Objectives

Table 5 (on the following page) summarises the project objectives and how successful DMRI was at achieving the project objectives.

- Clamping → DMRI successfully converted the Phase 1A prototype rig during Phase 1B to have an automated clamping and alignment system.
- Featherbone → with the use of the 'top clamp/guide' (refer Figure 35) ensures that the featherbone plough automatically traverses under the featherbones as required. Not using this guide on at least one occasion resulted in the plough traversing along the top of the featherbones. DMRI successfully completed this project objective.
- Chine bone sawing → DMRI demonstrated that the chine bone could be successfully cut with the saw and jig developed. However additional work needs to be focused towards:
    - optimising the saw profile, and
    - how best to position the saw cut relative to the spinal cavity or some other reference point.

  As such DMRI, having developing an example of a solution approach, still requires addition input, although this is not vital for the next proposed Phase. This objective was partially met by the project team.
- Striploin Rib Removal → using finished product presentation (i.e. yield) as the indicator there was not one striploin that was acceptable before John, Sean and the DRMI team commenced either undertaking rib knife profile changes or adding additional processing aids such as scribing ribs and/or the use of hooks to pull the striploin away as the rib knives traversed. As such DMRI did not successfully meet this project objective.
- Updated cost benefit analysis → although scored as a did not achieve by DMRI, this step was not actually undertaken. Until some of the previous points are addressed then updating the cost benefit analysis is not a justifiable use of project expenditure.

Table 5: Project Objective compliance

Objective		Compliance	Notes	Next Steps
1.	Clamping	🟢	Sufficient development undertaken until Phase 2 including automated clamping and simultaneous dynamic spinal alignment.	Revisit in Phase 2
2A.	Featherbone ploughing	🟢	Sufficient development undertaken until Phase 2.	Revisit in Phase 2
2B.	Chine bone sawing	🟠	New saw blade profile/speed required. How deep should cut be made? How will the final machine make this determination?	Revisit in Phase 2
2C.	Striploin rib removal	🔴	No acceptable meat recovery rates without consideration other actions being undertaken to assist machine. Significantly and repeatedly/reliably achieving acceptable yield recovery rates when performing this cut is to be the main focus of proposed Phase 1C developments.	Focus of Phase 1C
3.	Updated cost benefit	🔴	Not commenced	Complete after proposed Phase 1C but before Phase 2

4.7.2 Results Analysis

Considering only the successful yield trials, Table 6 highlights the additional actions that were undertaken that theoretically enabled success.

Table 6: Summary of additional operations benefit

Striploin	Outcome	Rib Scribing	Hook Pulling	Mod. Knives	Featherbone Scribing	Analysis / Questions
5	🟢	⚪	🟣	⚪	⚪	Pulling of the striploin with hooks improved the yield recovery. Why? Does pulling of the meat assist the rib knives in following the ribs better or does it remove the cut meat from potential damage of subsequent knives?
6	🟢	🟣	🟣	⚪	⚪	Scribing of the ribs ensures intercostal meat is recovered from the rib bones.
7	🟢	⚪	🟣	⚪	⚪	Again demonstration that the use of striploin hooks resulted in an acceptable yield. Support Striploin #5 results.
8	🟢	🟣	⚪	⚪	⚪	Supports Striploin # 6 results.
9	🟢	⚪	⚪	🟣	⚪	Modified knife profile with no additional assistance resulted in an acceptable yield. Is it possible to get a 'perfect average' knife profile and not need other assisted devices such as rib marking and striploin hooks?
10	🟢	⚪	🟣	🟣	⚪	New knife profile was not adversely affected by using the Striploin hooks. If anything yield increased by recovering a small percentage of intercostal meat.
11	🟢	🟣	🟣	🟣	🟣	This is still the ultimate approach to recover maximum yield via recovering all intercostals.
13	🟢	🟣	⚪	🟣	🟣	Confirmation of results obtained in Striploin #11.

The three things that need to be discussed and agreed to prior to Phase 1C commencing are:

1. Does the Australian industry want to recover intercostals on the striploin?
2. Is it realistic to expect to obtain a 'perfect average' rib knife profile such that other actions such as striploin hooking is not required?
3. Should the DMRI team focus on a mechanism for the equivalent of striploin hooking and get a better understanding of such an approach in the proposed future machine?

From Scott Tech.'s perspective the following are comments on the above questions:

1. Intercostal recovery → If yes then is the industry prepared to apply human operators to undertake the required pre-work prior to processing in a completed DMRI machine? If no then DMRI should have a focus on this in Phase 2. Hence develop an automated scribing/marking solution.
2. Rib Knife Profile → Scott Tech. believe that this is not possible and although additional work is required to get better 'averaged' profiled knives it is not the main solution required to increase the yield recovery of the current system.
3. Additional Processing → Scott Tech. believe that a focus for DMRI under the proposed Phase 1C is to develop/evolve the rig to achieve the equivalent of using the Striploin Hooks. Either by automating the hooks or an alternative approach such as jig orientation, vacuum systems or pushing systems on the striploin primal.

4.7.3 Brainstorming Session

On the final day the project team undertook a brainstorming activity to summarise what was learnt throughout the week, add additional thoughts/concepts and deduce possible options to move forward and recommendations to MLA.

What do we know from the trials (and other knowledge)

- There is significant variability within and between each striploin compared to the pork industry.
- Spinal cord cavity may not be sufficient as an alignment methodology.
- Third rib knife appears to be too long. Need to shorten the third knife and add a fourth knife.
- Bone abnormalities are causing yield loss. Refer Striploin No: 1, where a rib that was protruding, 'pushed' the rib knives away from the other ribs and resulted in lost yield.
- Australian processors have been known to add additional labour to recover additional yield, primarily intercostals. With striploin valued at $21/kg and trim at $3/kg, a processor has the opportunity to add labour and recover additional yield. The lesson from this,

particularly pertaining to the striploin, is that yield is a stronger focus of Australian processing companies than labour saving, and although labour is difficult to attract companies will place labour on tasks such as this that are yield sensitive. As a result it will be difficult, if not impossible, to sell a machine to the Australian sector that reduces yield over current manual operator standards.

- Pre-work of striploins prior to being processed in the DMRI rig increased yield. A combination of rib scribing/marking and striploin pulling with hooks.
- The scope/focus of the project has changed since the commencement in the sense that Australian processors are focusing more on striploin yield than in the past and hence results in an additional level of yield scrutiny on any developments in this area.

What do we don't know from the trials

- Is it a straight chine bone saw cut relative to the spinal cavity or does the distance between the spinal cavity and the place for cutting vary along the length of the striploin?
- Does 'pulling' the striploin with hooks increase yield every time?
- Circular chine bone saw → is there a better profile saw and what is the optimum speed?
- There is a large variation in Australia of striploin sizes. What are these? (initially the project should only focus on a reduced size range).
- Will DMRI's pork rib puller work on beef? This is only important if the project heads in the direction of cutting through the chine bone completely, aka the JBS Loin Saw.
- What was the BLM clamping reference points? Can any knowledge from the BLM system be used to enhance/inform the DMRI developments?
- Is there a mathematical model to determine where to clamp?
- Where is the best place in the upstream processing chain for an operator to undertake any pre-work that may ultimately be required with the final solution (i.e. for rib marking)?
- How do we set the chine saw depth?
- Could we use vacuum to hold the striploin bone set rather than the current clamping 'spinal system'?
- Could a vacuum system be used instead of the hooks used on the striploin?

Future Aspirations

- Process a beef side like pork is processed in Europe with automated equipment. Hence the side is laid down on a conveyer and commences the deboning process horizontally not vertically as currently is the case.
- Need to target a beef processing cycle time of 45 seconds per body.

Chine Saw Cut – Partial Cut (status quo) or Through Cut (aka JBS Loin Saw)

- Through cut
  - Positive aspects
    - We can do this operation now.
    - Increases weight of the striploin.
    - Good presentation.
  - Negative aspects
    - Currently requires additional labour to remove ribs and 'nipple' bones.
- Partial cut
  - Negative aspects
    - An additional bone (chine bone) to clean (remove meat from).
    - Decreases striploin weight.
    - Increased trimmings.

Possible next steps and items to address

- Is there any benefit in using the Scott Technology 'Beef City' Loin saw laser alignment concepts to assist in position where the loin saw makes a cut?
- Is there a need to understand the beef bone structure better and the variations? This could be a good university student project.
- The range of product (i.e. small, medium and large, soft sided or not soft sided) is continuing to hamper the developed progress. Taking the rig to a processing facility where DMRI can obtain more samples at a cost effective price and 'hand select' the striploins, would be an invaluable approach to further development.
- Developments should focus on a fixed range of product sizes, although long term a commercial solution needs to cater for all sizes. In the short term the project could concentrate on a company such as Beef City, ACC or Kilcoy who have a controlled sized of animals that are being processed.
- New knives are required → Knife one profile is acceptable however knives two and three require additional work. The third knife is too long and at least one additional knife (a fourth knife) needs to be added.
- Striploin Hooks → These appeared on all occasions to increase yield, however on some occasions yield was acceptable without the use of hooks and may provide the ultimate solution with a insurance policy pertaining to reliably achieving required yield recover levels. May need a 'balloon concept to 'push out' the intercostals rather than using hooks.

5 Conclusions and recommendations

In the rigs' current configuration, before the evaluation week by John Hughes and Sean Starling, the rig arguably did not produce an acceptable result overall based on the yield recovery of each of Striploins 1 – 5 processed.

Applying additional operational procedures such as marking the ribs before processing, applying hooks to the striploin and pulling the loin as the rib knives traversed and adjusting the profiles of the knives substantially increased the yield recovered to an acceptable level.

The question now stands…

Is it worth applying the additional operational concepts evaluated to the rig and determine if they provide a 'hands off' solution that results in acceptable yield recovery of each striploin?

Discussions with DMRI, John Hughes and Sean Starling on Friday 8th July 2011 identified that Ove Vasvari was not as heavily involved in the project as both DMRI and MLA had anticipated due to other commitments.

Ove discussed and visually demonstrated around a meeting table some of the concepts he had that could take the findings from the 'additional operational concepts' and apply them to the rig to significantly enhance the yield results.

John Hughes and Sean Starling both recommend and support such an approach and that the Australian industry further support DMRI, under the guidance of Ove, for a maximum of a three month duration to apply the lessons learnt to the rig and demonstrate the improvements to John and Sean.

A large cost of the development work to date has been the procurement and disposal of striploins for testing. In addition to the financial cost of purchase and the time taken to collect the striploins DMRI has limited control over the size and 'soft sidedness' of the acquired striploins. John Hughes and Sean Starling recommend that for all future developments the rig should be relocated to a suitable Beef processing facility 'near' DMRI for all product testing.

6 Appendix A – Loin Yield Specifications

6.1 KPIs

The purpose of setting the production and processing KPIs is:

1. To provide DMRI with a targeted end result from both a product and production integration view point.
2. To enable MLA to determine when best to send John Hughes to Denmark to sign off the developments and hence make relevant project progress payments.
3. To form part of the on-going commitment document still to be drafted between MLA and Scott Technology.

For the purpose of objectives 1 and 2 above, the KPIs will be defined with respect to:

1. Primal appearance
2. Bone cleanliness

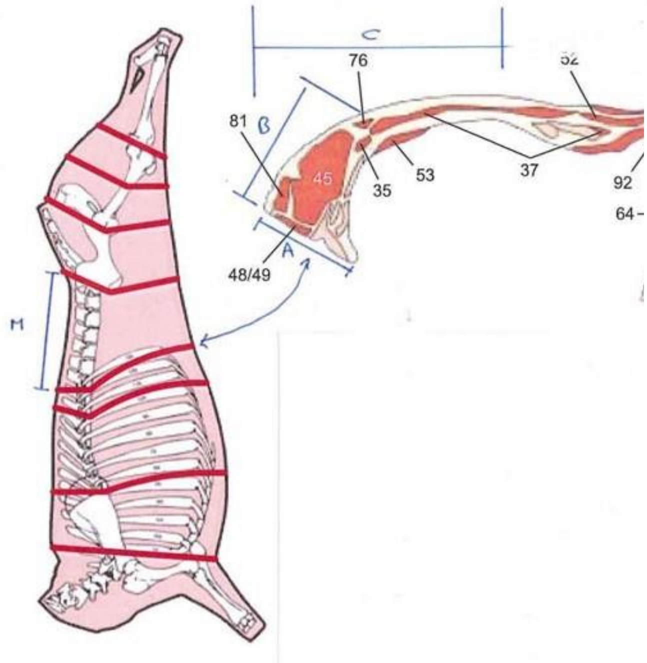
6.2 KPIs determination trial work

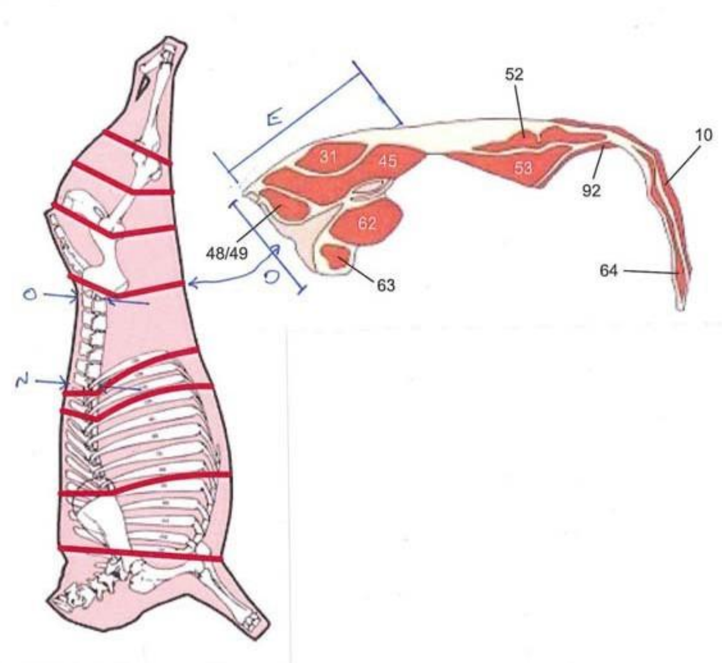
The data collected was obtained as follows:

1. Two left and two right loins where obtained from random sides of beef during 'OptimumCut' production run.
2. Each of the four loins was measured (refer Table 1).
3. Each of the four loins was manually boned, with no operator pressure being applied, on a table away from the side boning chain. Each loin deboning activity was videotaped. Each loin was boned by the same operator.
    a. The purpose for removing the loin from 'OptimumCut' side chain is that 'OptimumCut' do not debone the loin on the chain in an analogous way that simulates the approach to be achieved with the DMRI proposed solution.
4. Each resulting bone and primal parts where photographed.
5. Two additional loins where deboned after being processed in 'OptimumCut' loin bandsaw. Hence total number of loins deboned was six.
6. The two additional loins where boned by the same operator as above, videotaped and photographed.
7. The first additional loin was processed through 'OptimumCut' loin saw and is the average standard 'OptimumCut' expects from its current operators. A commercially viable machine from the R&D would potentially be measured against this standard by 'OptimumCut'.
8. The second additional loin was also processed through the 'OptimumCut' loin saw and the boning operator taking all care to remove only bone. The purpose of this additional bone-out is to show what a platinum boning standard would be. Hence the most amount of recovered meat on the primal. However this is not typically achieved consistently throughout a whole day's production.

6.3 Measurement Referencing

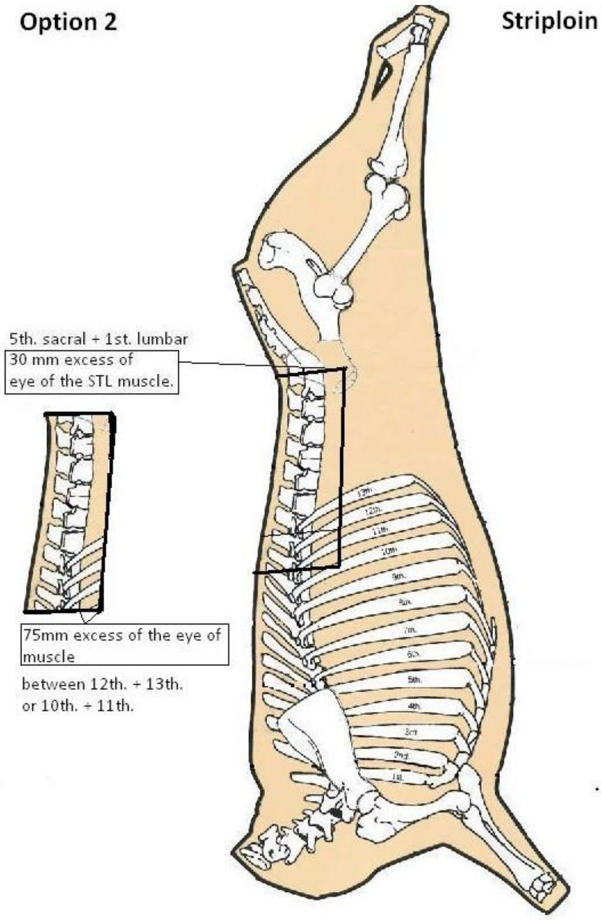
The following two images (taken from the AusMeat handbook) are used to depict the measurement locations referenced in table 1.





Note: The above has been provided to capture the measurements of the loins deboned during the trial. As part of the first Phase 1A all parties agreed that the following is the specification of the loin (i.e. the raw material) to be presented and processed by the DRMI developing machine. The following extract does not allow for the last two ribs, at their full length, to be included on the loin and presented to the machine.

Striploins to be processed have during phase 1A (A.TEC. 0071) been defined in e.g. "The measuring scheme" as to be a cut 30 mm from the Eye Muscle at causal end to 75 mm of Eye Muscle at cranial end by a straight line.



6.4 Measurement Results

Refer to the previous images for letter referencing and appendixes for scanned photos.

	Left 1	Left 2	Right 1	Right 2
Overall				
Length (M)	570	600	590	560
Cranial End				
Chine/Feather Width (N)	190	180	190	185
'Eye Muscle' Length (B)	245	160	170	230
'Eye Muscle' & Chine (A)	170	230	265	165
Backbone to cut off rib length (C)	482	530	570	500
Caudal End				
Chine/Feather Width (O)	170	180	160	180
'Eye Muscle' Length (E)	250	240	210	230
'Eye Muscle' & Chine (D)	140	160	130	150

Table 1: Loin measurements (Note: all measurements are in mm)

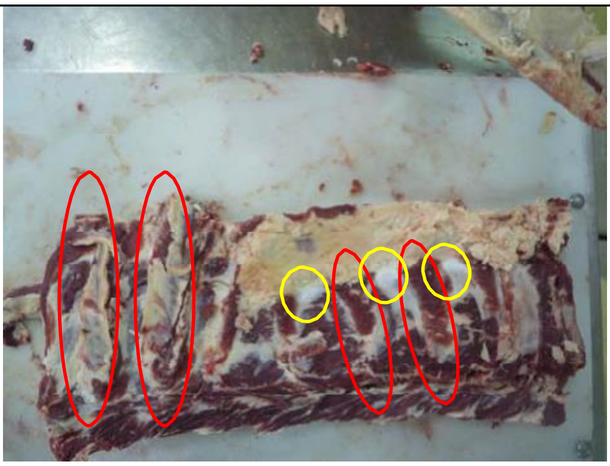
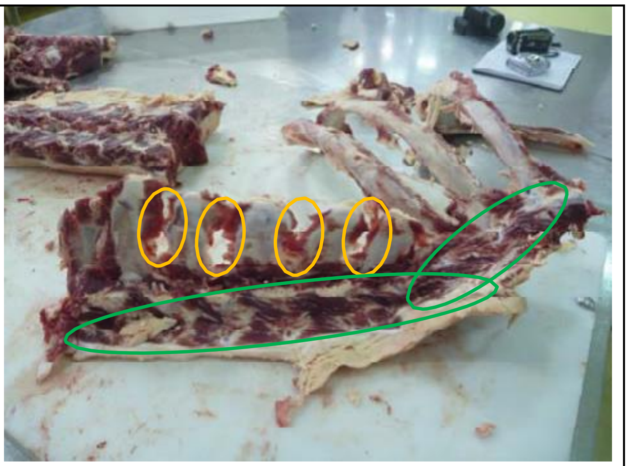
6.5 KPIs (acceptable standard)

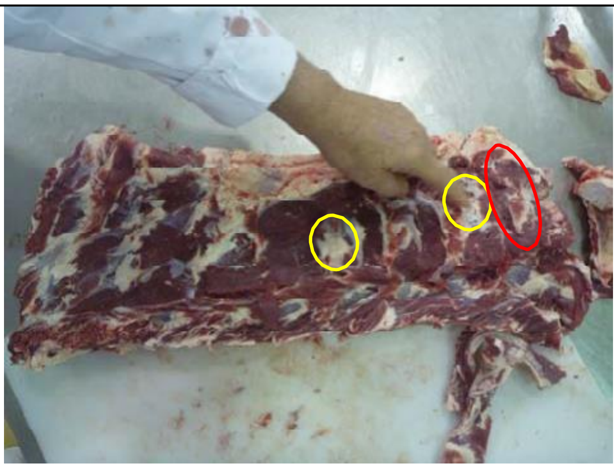
Primal Recovery and Bone Cleanliness

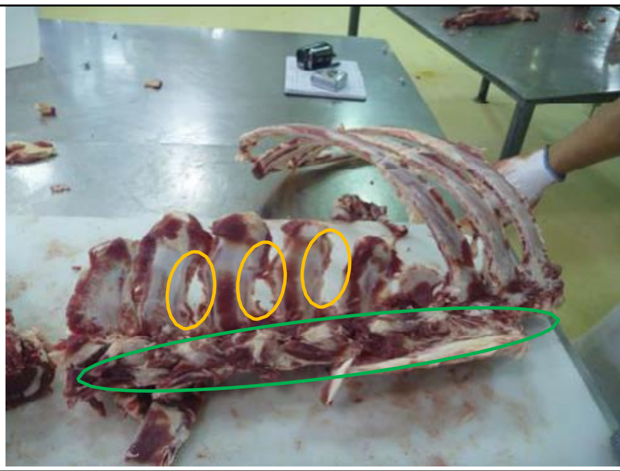
It is expected that an acceptable result for the DMRI system is depicted in the following four boned loins and resulting 'loin bones'.

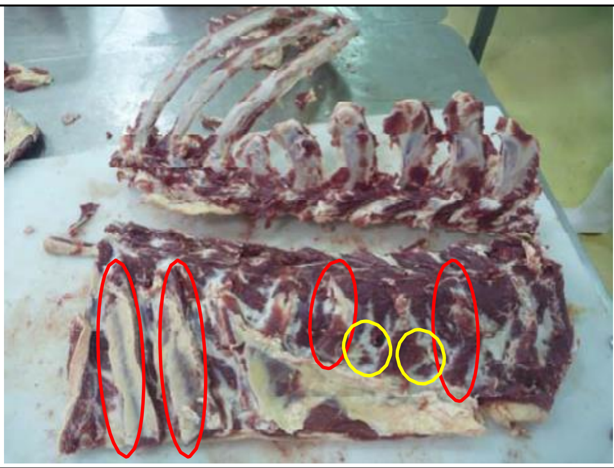
Of particular importance is the significant quantity of the intercostal (red circles) remaining on the loin muscle group and remnants of the featherbone cartilage (yellow circles) on the loin muscle group. These are positive outcomes and are to be replicated by the DRMI machine.

The 'loin bone' is not completely void of meat residual as shown. However there is not expected to be a continuous fill of meat between featherbones (orange circles). An amount of meat along the backbone that is able to be grabbed between two fingers and removed by hand (green circles) would not be acceptable.

	
Left 1 Loin	Left 1 'Loin bone'

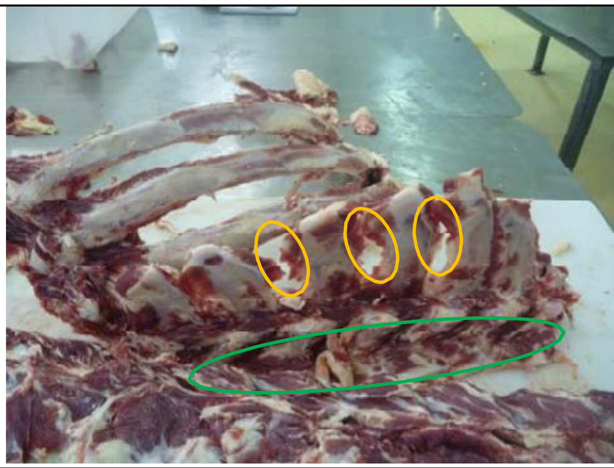

Left 2 Loin


Left 2 ‘Loin bone’


Right 1 Loin


Right 1 ‘Loin bone’


Right 2 Loin


Right 2 ‘Loin bone’

6.6 ‘OptimumCut’ Production Line Standard

‘OptimumCut’ utilise a chine bone saw and then wizard from residual featherbone ‘knobs’ from the loin muscle group. The following two loins were taken from the ‘OptimumCut’ production line, and represent the ‘OptimumCut’ standard.

	
‘OptimumCut’ Loin ex Loin Saw	‘OptimumCut’ Loin deboned ex Loin Saw

6.7 Platinum Standard

The following depicts what is now referred to as the platinum standard. It is not expected that any human operator could achieve consistently this result. It is shown for a measure of the maximum yield recovery possible.

	
Platinum Standard Loin	Platinum Standard ‘Loin bones’

6.8 Videos

Video footage of each of the bone outs is available.

7 Appendix B – Step by Step rig operations

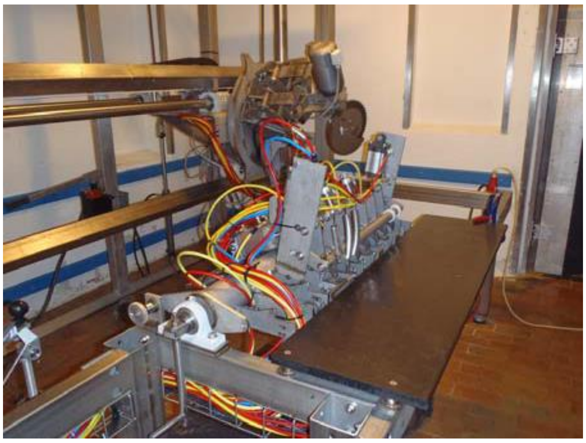


Fig 1: Rig in ready to load orientation

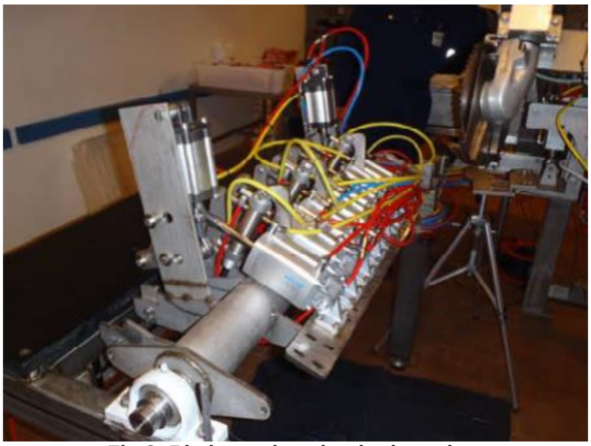


Fig 2: Rig in ready to load orientation

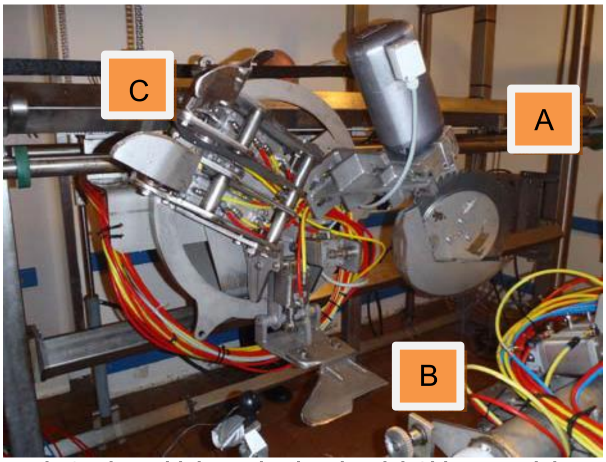


Fig 3: Rig multiple cutting heads – (A) Chine saw, (B), Featherbone blade and (C) 2 x rib knives

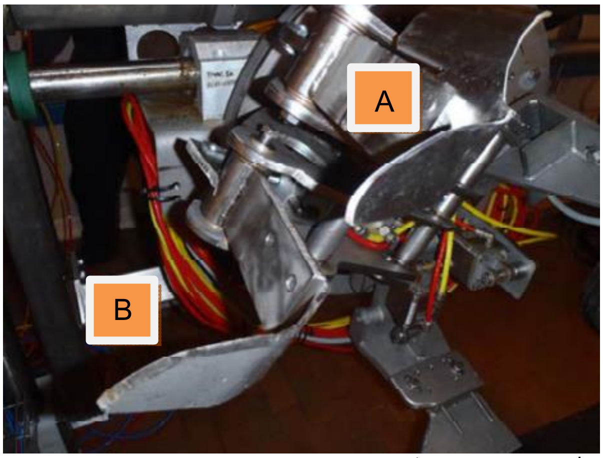


Fig 4: Rig multiple cutting heads – (A) 1st rib knife, (B) 2nd rib knife

Fig 5: Rig multiple cutting heads – Featherbone blade

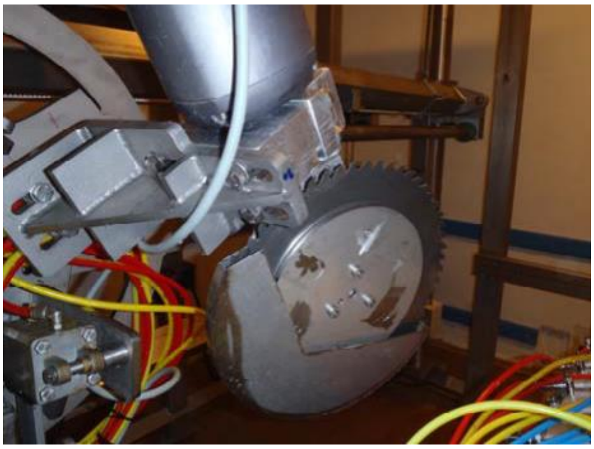


Fig 6: Rig multiple cutting heads – Chine saw

Fig 7: Rig control panel

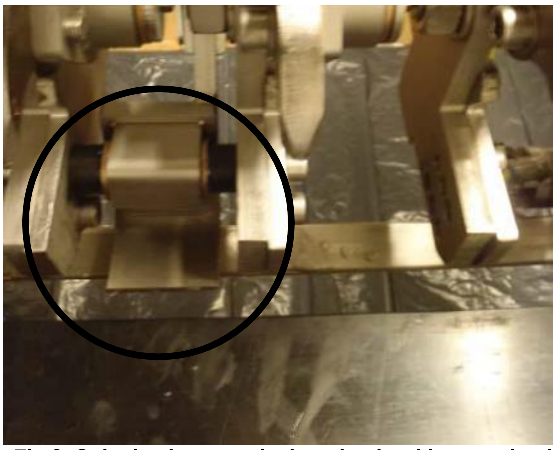


Fig 8: Spinal column cavity location lug (de-energised position)

Fig 9: Spinal column cavity location lug proximity sensors(used to energise location lugs as guide traverses spinal column cavity- refer Fig 10)

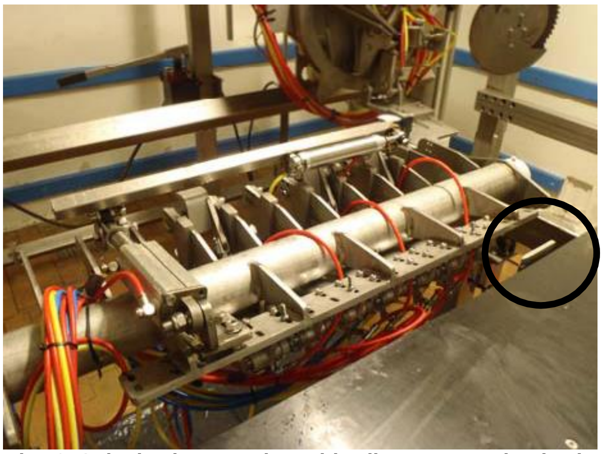


Fig 10: Spinal column cavity guide alignment mechanism)

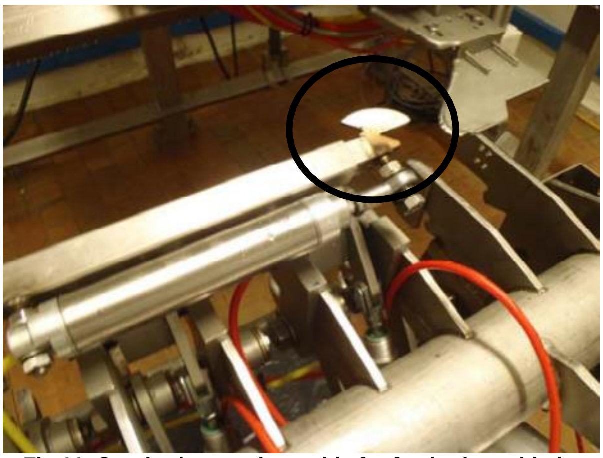


Fig 11: Starting/separation guide for featherbone blade

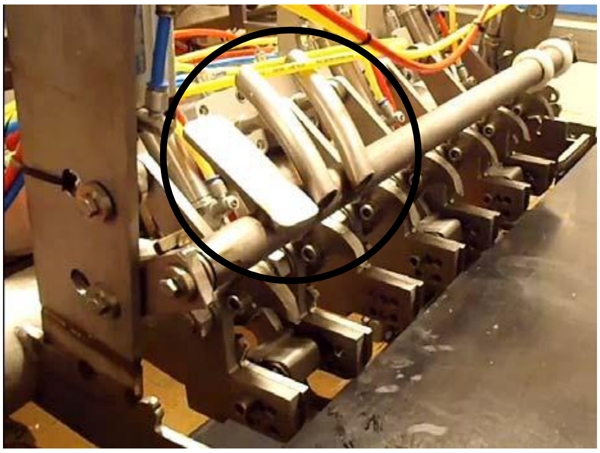


Fig 12: Guides to accommodate differences in width between the varying shapes of the round rib and flat ribs