final report

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Automated beef back boning – Stage 1

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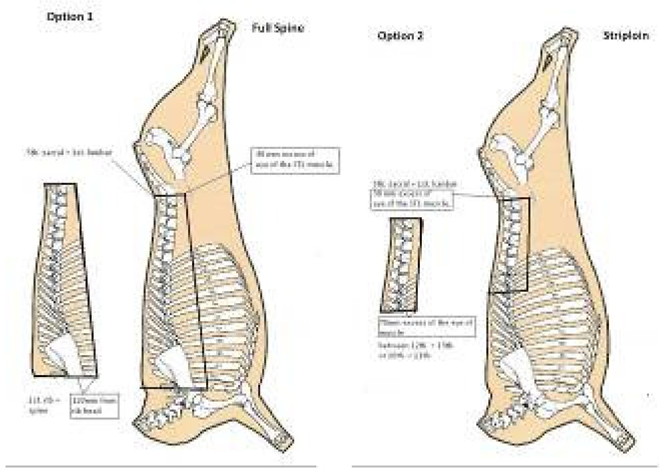
Executive summary

In a previous feasibility study jointly funded by MLA and DMRI (P.PSH.0358 - Improved efficiency in beef deboning - feasibility study), three operations were identified as having the potential to be automated in a cost effective manner. In particular, the operation that showed the highest potential return was beef back boning.

In that study it was estimated that, if the back could be boned out automatically, a labour reduction up to 6 operators would be achieved. For a meat processing 50hds/hr backs per hour in two shifts, a payback time of less than two years could be realistic.

It was made clear that the full development of an automated system to debone beef backs would span across 3 to 5 years and require and investment of at least $2-3M. With that in mind the first step in the process was defining the scope of the project. In November 2009 MLA and industry representatives visited DMRI and discussed the scope of the current project and connection with next stages.

Four options were discussed (see Fig. 1 and Fig. 2 in main report) but it was agreed this development should only focus on the striploin (Option 2 in Fig. 1), as it was a reasonable compromise between feasibility and benefits. The current project, A.TEC.0071, or Stage 1, would try to deliver a basic way to clamp and hold in place the striploin, allowing separation of the bones from the meat while meeting industry expectations in terms of yield and finishing. The outcome of the project will be several trials where a testing rig or workbench would be tested with product to evaluate the viability of the approach.



This assumption relied on DMRI’s ability to design a machine capable to automate at least part of the process. DMRI would be leveraging on their past experience to successfully automate the de-boning of pork middles, a technology installed and operational in dozens of plants in Europe and commercialised by ATTEC.

A development machine platform was constructed and tested delivering results that were encouraging, sufficient to consider moving to the next phase.

Contents

1 Background

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2 Project objectives

It was made clear that the full development of an automated system to debone beef backs would span across 3 to 5 years and require and investment of at least $2-3M. With that in mind the first step in the process was defining the scope of the project. In November 2009 MLA and industry representatives visited DMRI and discussed the scope of the current project and connection with next stages.

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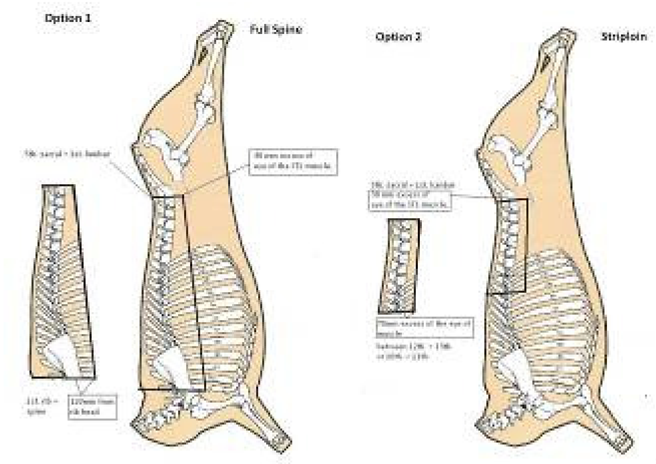

Figure 1 Options 1 and 2

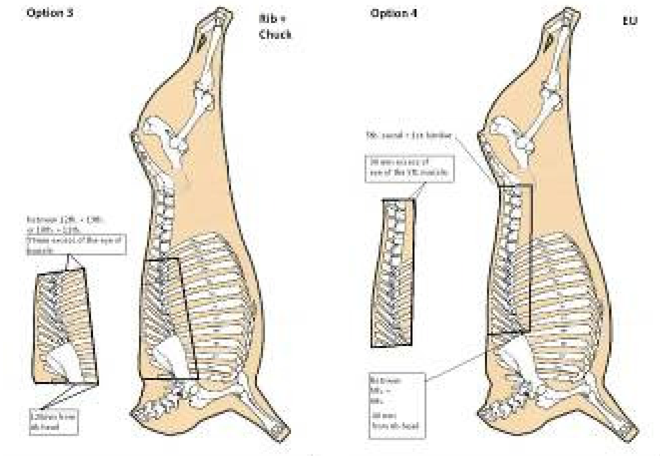

Figure 2 Options 3 and 4

3 Methodology

After taking on board the feedback and comments provided in the initial meetings between DMRI and Australian industry representatives, DMRI's engineers have proposed a concept that relies on a number of tool stations common for both left and right sides to avoid the need to install both Left and Right hand machines. The stations would be equipped with left and right side knives, but the machine frame and major components would be common to both.

Under this first concept the machine will be manually loaded with the striploin flat on the spine plane (the symmetry plane of the carcass through which it has been split early in the process), ready to be locked and secured by the gripping mechanism. After the spine is locked, the whole striploin will be rotated 90^{o} to its first cutting station (workstation 1 in Fig. 4), where a knife will separate the meat from the featherbones by a cut parallel to the carcass symmetry plane.

Meanwhile the operator will load the next striploin. After the first operation is completed in workstation 1, the striploin will be rotated another 90^{o} to the next station (180^{o} from the loading station), where a set of 3 knives or more will gradually separate the boneless cut from the ribs. The boneless cut will be dropped onto a conveyor. Finally, after another 90^{o} rotation (270^{o} from the starting point), the bone will be released onto another conveyor.

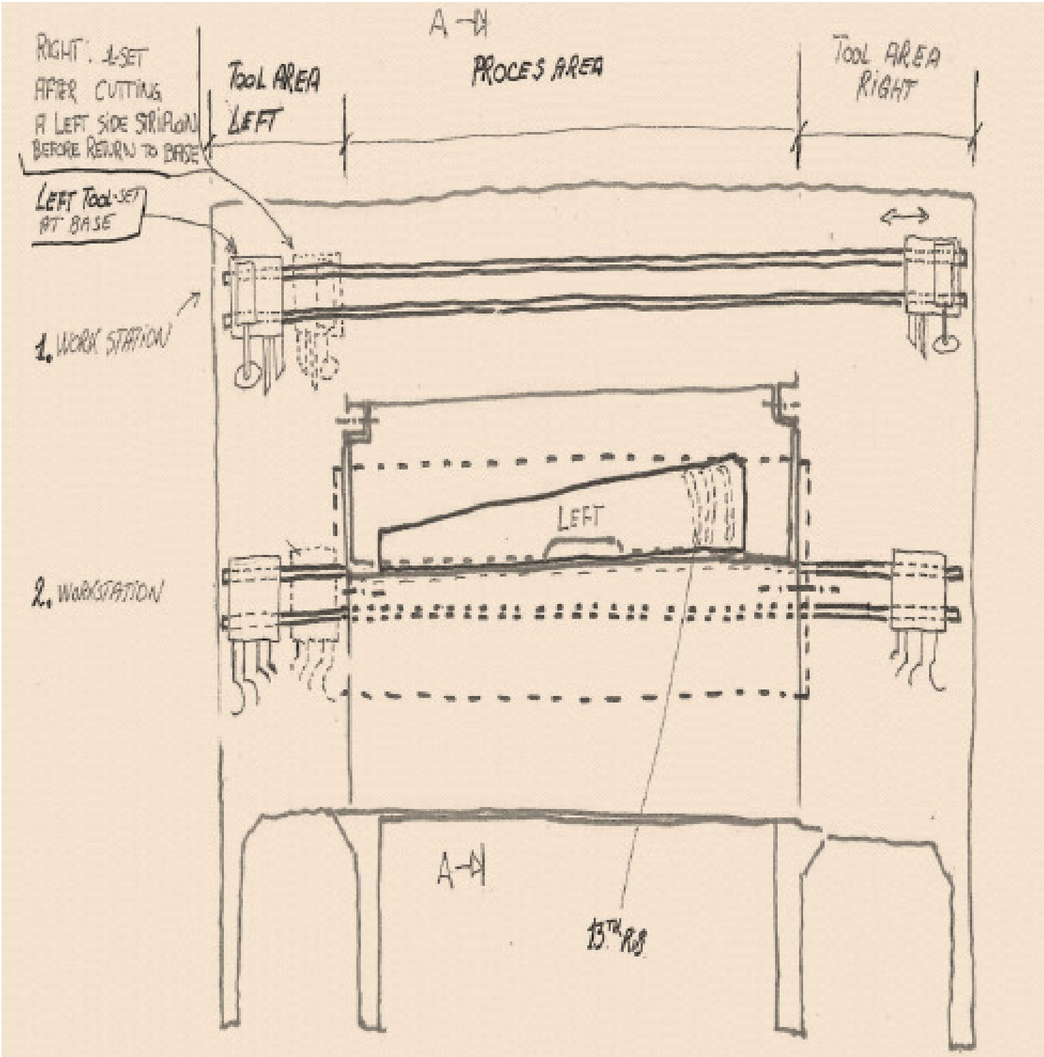

Figure 3 – Front schematic view of the machine

The machine will be capable of de-boning both left and right sides but probably left and right hand knives will be used for each operation. The system will need to know whether it is cutting a left side or a right side beforehand. This information may be provided by the operator or through some automated detection system.

Figure 3 shows a front view of the machine, and a section A-A is detailed in Figure 4 to describe the sequence of operations.

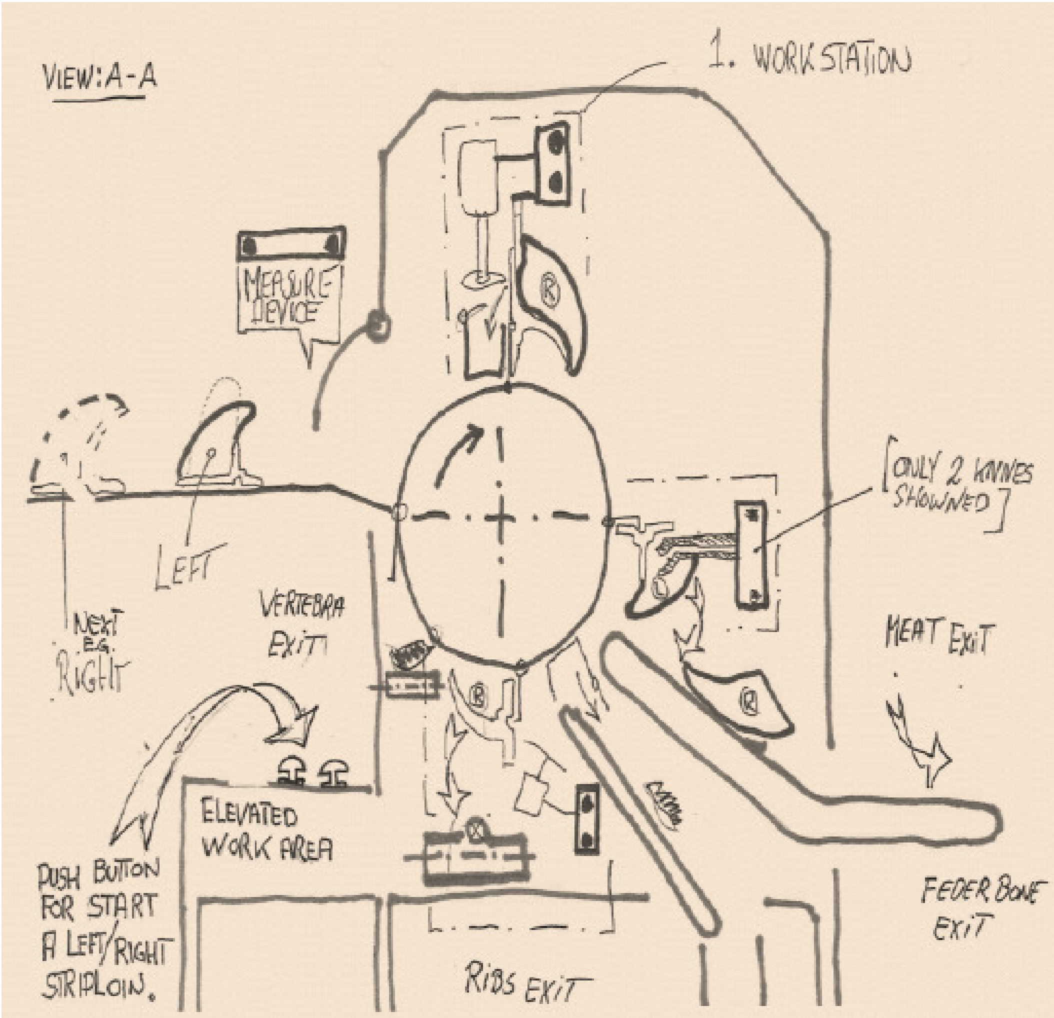

Figure 4 – Schematic operation of striploin machine

Workbench description

DMRI has designed and built under the current project a work bench to test the basic principles upon which a future system would be based on, and that have been described above. In particular, the work bench was meant to be used to:

- Test how the spine can be clamped
- Define the initial cutting and sawing patterns to allow clean bone removal

Figure 5 shows a CAD image of the basic frame of the work bench, and Figure 6 shows an actual image of the rig. Figure 7 shows a view from above of the work bench with axis directions, and where the cutting plate/blade can be seen at the top right corner.

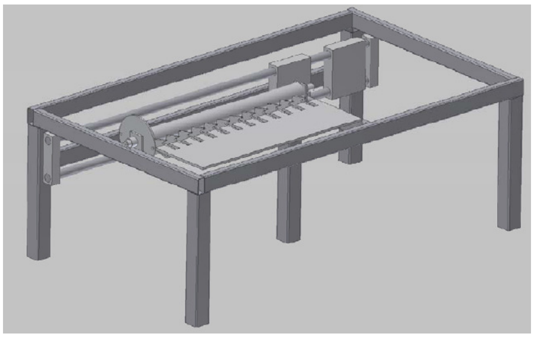
Figure 5 – Work bench frame


Figure 6 – Actual Work bench

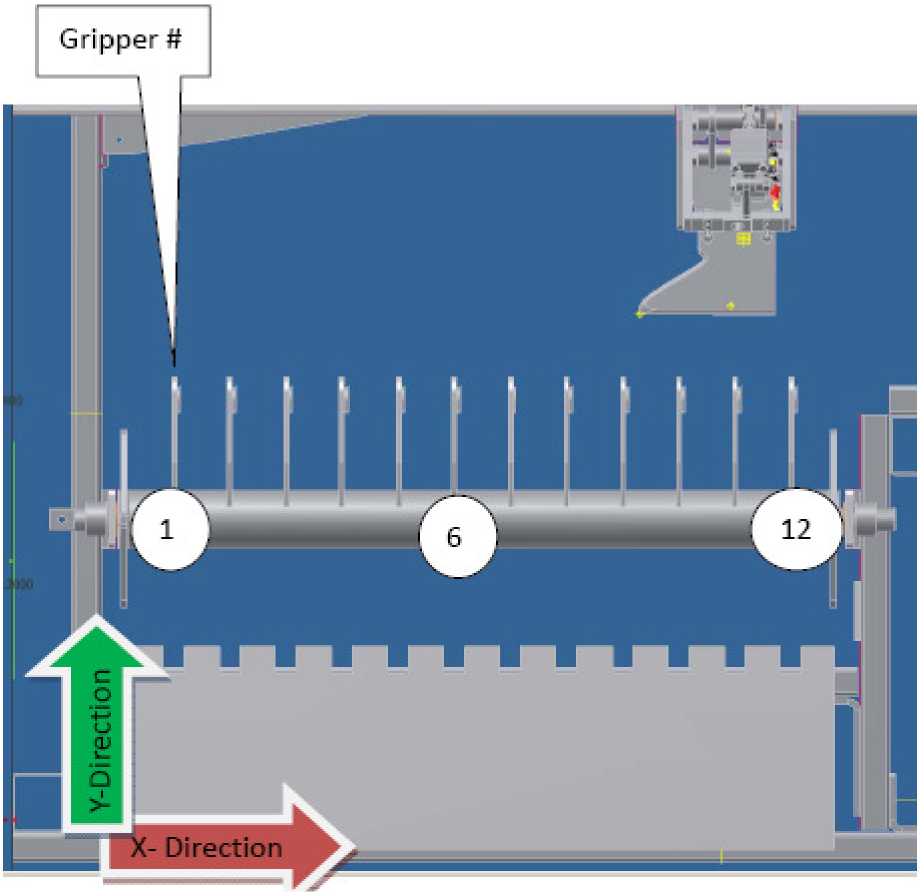

Figure 7 – Axis detail and gripper

Trials

A group of Australian representatives formed by Dean Goode (Kilcoy Pastoral), John Heart (John Dee Warwick), Peter Cody (V&V Walsh), John Hughes and David Doral (MLA) visited DMRI in May 2010. Brian Rekittke from Scott Technologies was also present at the demonstrations on the second day.

During this visit two set of trials were observed, the first one on May 18th and the second one on May 20th, this last one implementing some of the recommendations made by the Australian representatives after the first tests. The following features were demonstrated:

- Clamping of spine
- Cutting plate
- Saw cut

The tests focused mostly on the separation of the feather bones from the meat with a 12mm thick cutting plate (a sort of rigid knife shown in Figure 8), and the gripping/clamping mechanism as the underlying concept that will make all the operations possible.

The actual cutting of the feather bones was tested too, although this operation was not considered critical. No cutting or separation from the ribs was demonstrated at this point.

Figure 8 – Cutting plate

First day of trials – May 18th 2010

On the first day we familiarised with the work bench first and then basic feather bone separation tests were performed with five striploins.

Figure 9 – Attaching the cutting plate to the work bench

Figure 10 – Striploin locked in position

Figure 9 shows how the cutting plate is mounted on a self compensating slide for vertical and horizontal position change.

Figure 10 above shows the striploin locked in position after the clamping operation. In Figure 11 several photos show how the striploin was loaded manually and locked on the clamping rig. Note that although the loading process will most probably be manual in the first commercial system, the clamping action (performed also manually in the work bench with the help of a lever), will be fully automated.

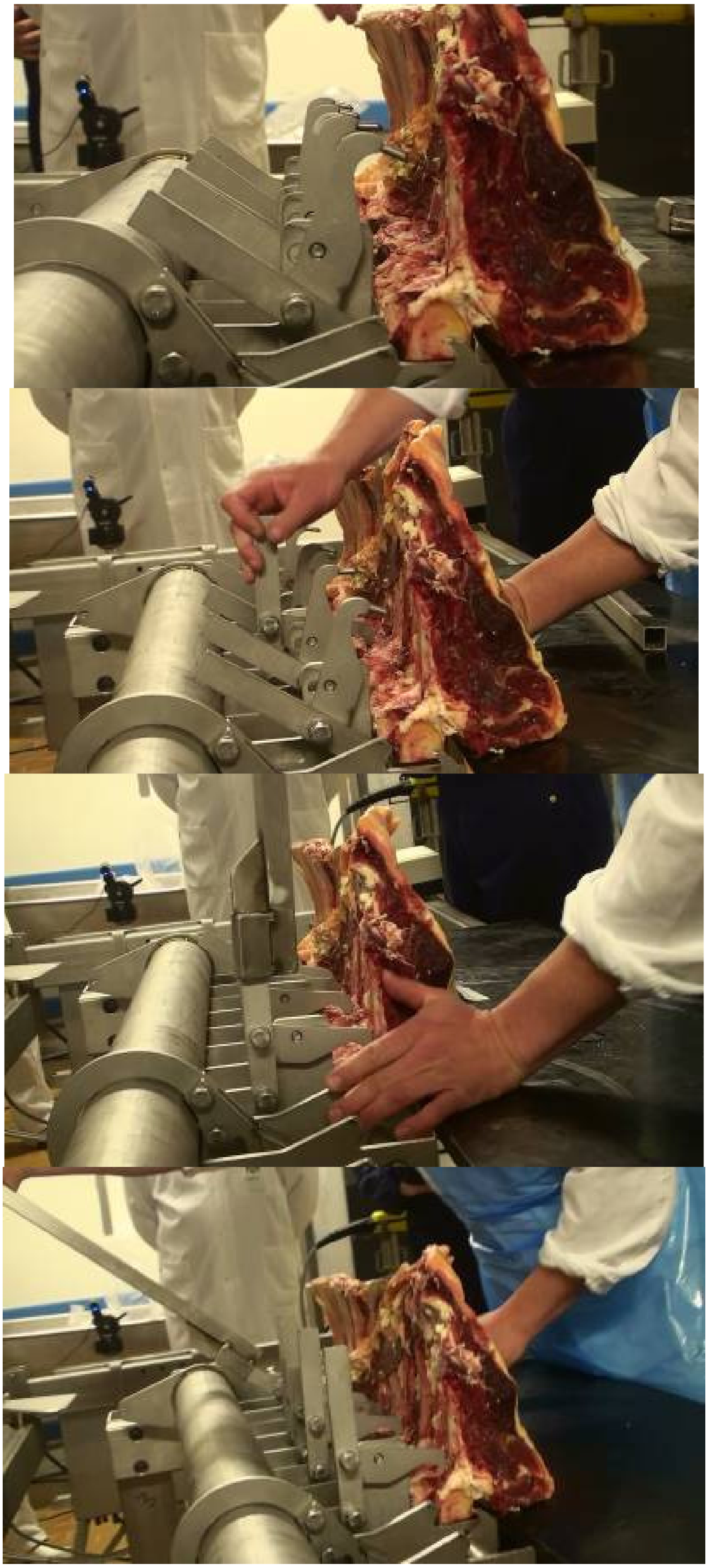

Figure 11 – Clamping

After the striploin was loaded and locked in place, the clamping rig was rotated 180^{o} to the opposite position where the cutting plate slides to cut and separate the meat from the feather bones, as shown by Figure 12.

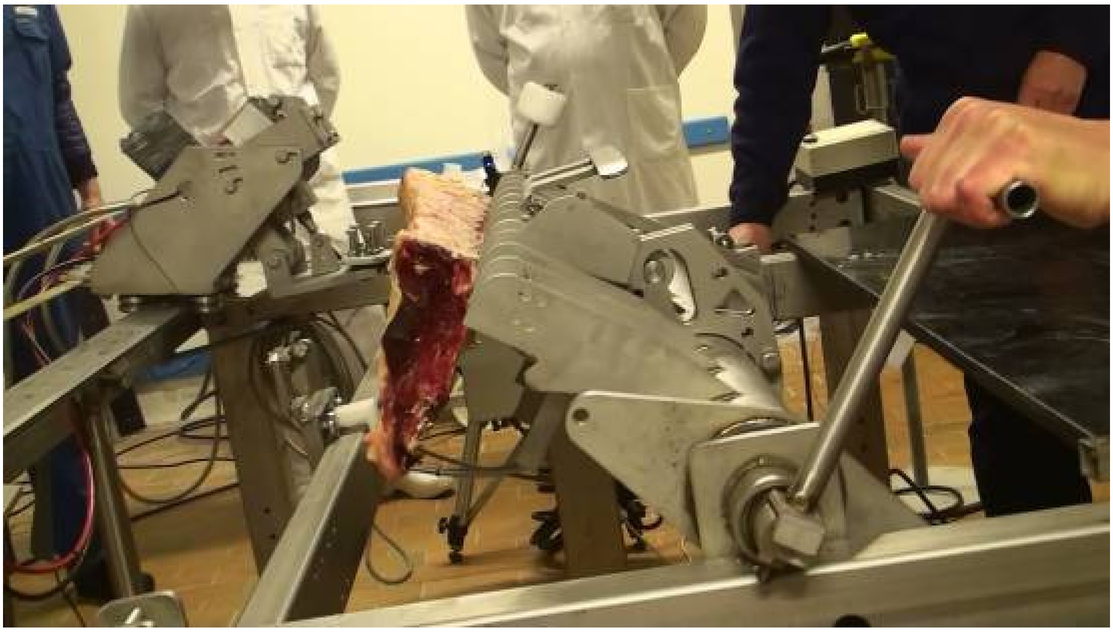

Figure 12 – Rotation

Once in position (Figure 13, see cutting plate at the top centre of the picture), the cutting plate will start sliding from end to end to separate the meat from the feather bones

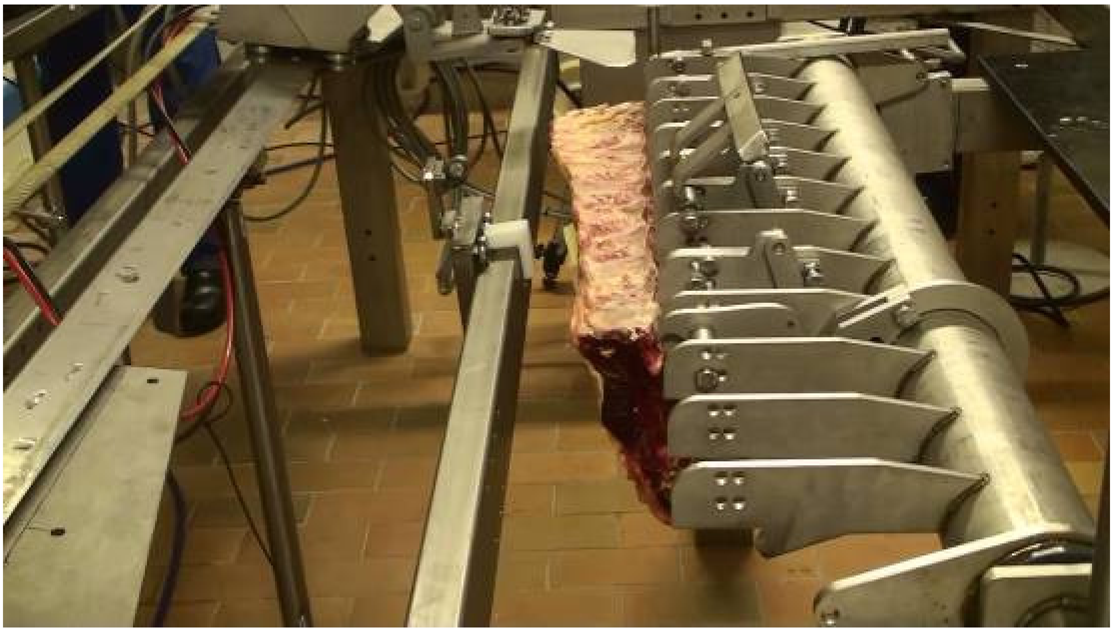

Figure 13 – Striploin ready for cutting

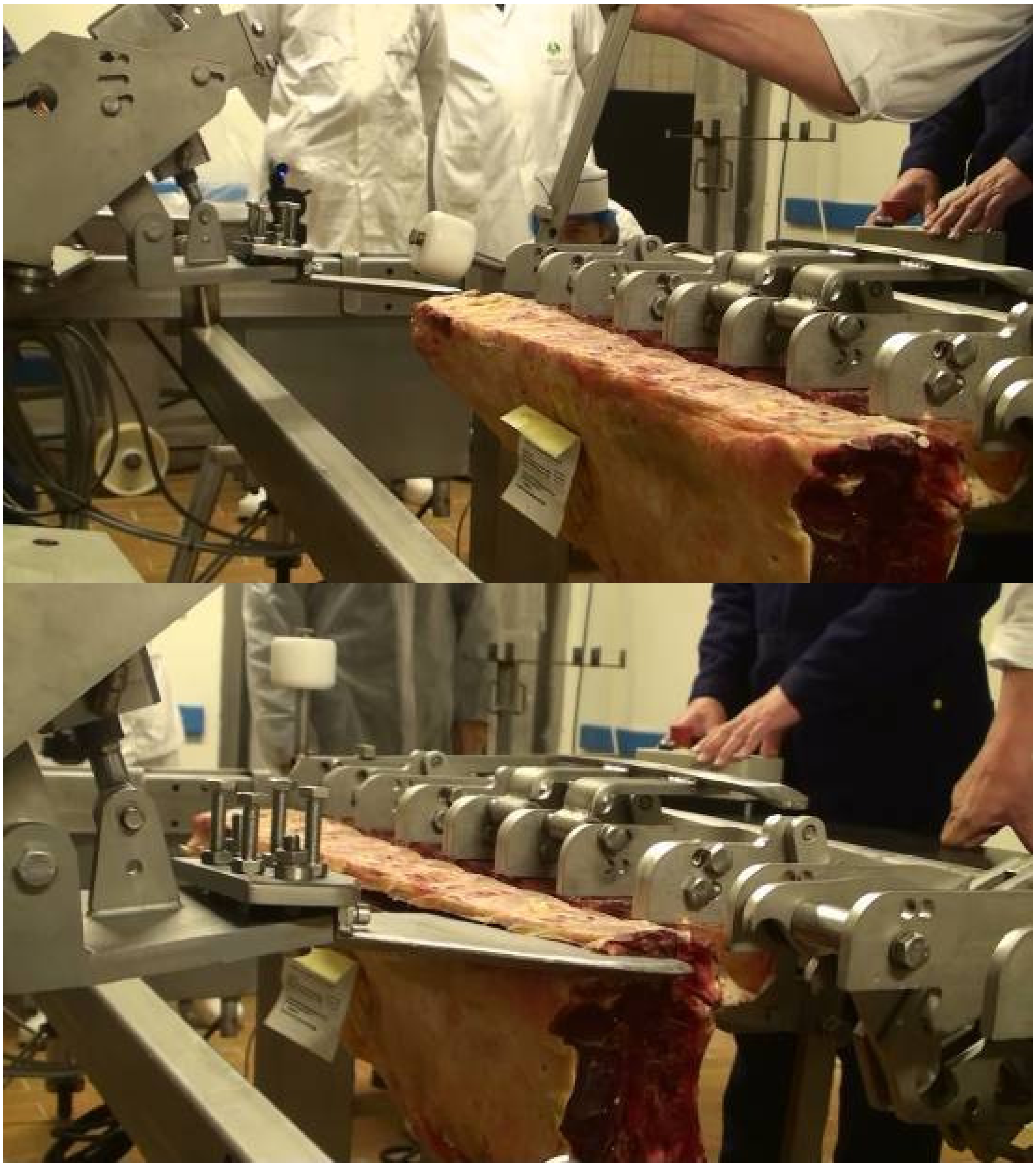

Figure 14 – Cutting action

In Figure 14 above two images show the beginning and the end of the cutting operation. The images show how the cutting plate was positioned with the help of a roller actuated manually with a lever, in order to set the entry point. This operation will be automatic in a commercial system. The lower image in Figure 14 shows how the cutting plate leaves the striploin at the other end.

Another view of how the cutting plate enters the striploin is showed in Figure 15

Figure 15 – Cutting entry point

All the tests during this first day turned out to be unsatisfactory, due to poor yield or because the blade cut through the feather bone, piercing it and cracking it.

Figure 16 shows results from the first striploin, where the cut was smooth and easy but the meat left attached to the feather bone was excessive for current standards.

Figure 16 – Visual yield

Figure 17 shows three snapshots of the same cutting test where the plate cut through the bone when trying to bring the plate closer to the feather bone. The most significant contributing factor to this outcome was the lack of support to the spine when the blade presses against the spine. The implementation of a supporting plate was the most important correction measure to be tested on the second day.

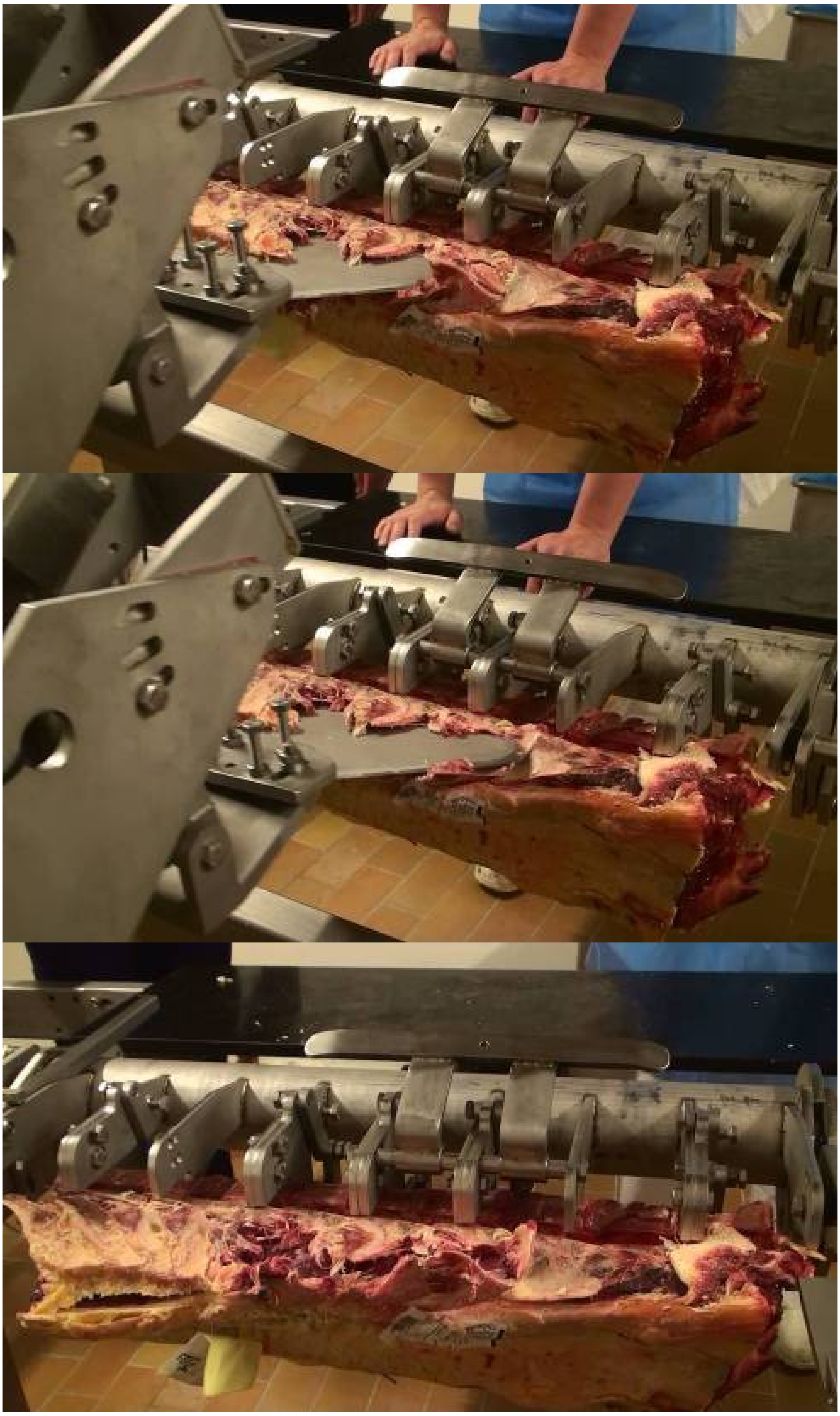

Figure 17- Plate cutting through the spine

In the following tests of that day other problems were encountered, like the blade getting stuck when pressing against the bone (Figure 18, with a blunt blade as contributing factor), or the blade deforming and detaching the feather bone from the spine (Figure 19). Those problems where emphasized by the fact the striploins tested came from carcass sides with a significant level of soft siding and even broken backs.

Figure 18- Cutting plate stuck against striploin

Figure 19 – Cutting plate deforming and detaching the feather bone

Apart from the feather bone separation from meat, the feather bone sawing and removal was tested. Figure 20 shows several snapshots of the sequence of operation. Other than this one time trial no special attention was paid to it as this operation was considered easier to implement, although future attention should be paid to the saw shape and material, the cut depth and determine whether the saw should only cut the spine 'knobs' or the 'knobs' and the ribs together.

Figure 20 – Feather bone sawing

In figure 21 the cut finishing can be observed once the feather bone was sawed and removed, and the quality of the cut indicates more meat than desired was left attached to the feather bone.

Figure 21 – Finishing with feather bone removed

The outcome from the first day of trials delivered an unsatisfactory result where either excessive meat was left attached to the feather bone or the blade crushed the feather bone when brought too close to it.

From the meeting held after the trials, the following recommendations were made to be implemented straight away and tested on a second day of trials, arranged for May 20th. In particular:

A. Install a support plate to keep the feather bone secured and stable on its plane
B. Cut from the other end. On this first day of trials all the striploins were cut starting from the cranial end (head side), and it was suggested to cut starting from the caudal end (tail direction), to provide better support when the blade enters the striploin
C. Sharpen the blade or cutting plate
D. Install a knife instead of a cutting plate on the rig to test whether the added flexibility would allow the knife to conform to the feather bone shape and provide better yield and overall cutting quality

Second day of trials – May 20th 2010

After the first day of trials, DMRI worked on the suggested improvements provided by Australian representatives' feedback. Four strpiloins were tested with the following results relative to each modification:

A. Support plate. This modification made a huge difference and was probably the single most important improvement. Figure 22 shows the support plate and how it leant against the spine on the carcass symmetry plane. Note that in this case the caudal end is positioned first, something that did not deliver a good result. Figures 23 and 24 show instead successful cuts with the most effective configuration with support plate and cranial end first.

Figure 22 – Work bench with support plate (caudal end first)

Figure 23 – First successful cut with support plate

Figure 24 – Detail of successful cut with support plate

B. Cut from the other end. Another suggested means to provide better support was to start cutting from the caudal end (tail) instead of the cranial end (head) as done on the first day. The rationale was based on the stronger support the shorter feather bones of the caudal end could provide compared to the longer ones from the cranial end. This modification was not effective probably because the blade enters at the right point on the caudal end and then is guided by the feather bone, relying more on its support and being guided by it precisely when the feather bones become slimmer and weaker. Results showed how the blade cut through the feather bones close to the end of the cutting line. Figure 22 shows a striploin positioned with caudal end first. Figure 25 shows how the blade or cutting plate cut through the bone at the cranial end.

Figure 25 – Blade cutting through feather bone at cranial end

C. Sharpen the blade or cutting plate. This was another obvious modification that improved results. The blade was sharpened for the second day tests and Australian representatives thought the blade of a commercial machine should be sharper than the blade tested. DMRI has contacted a provider of a new blade material, Vanax, with increased strength and ability to be sharpened, and even conformed to curved shapes, something very useful for the meat separation from the ribs.
D. Knife instead of a cutting plate. On the first day it was suggested a knife would be less rigid and might be capable to follow the contour of the feather bones, removing more meat. However, a quick test with a knife attached to the rig (see Fig. 26) on the second day did not perform satisfactorily, particularly when compared with the better results provided on the second day using the support plate. It was proven a solid cutting plate like the one designed in the first place by DMRI and tested in these trials had better chances to remove more meat, as long as adequate support was provided to the feather bones. A knife was probably too flexible and retracted when too much opposition was found without cutting through the meat. Although a very sharp knife could have performed much better, it was agreed most probably it would be an inferior solution compared to a very sharp cutting plate.

Figure 26 – Flexible knife

4 Results and discussion

After the two days of trials and based on the results from the tests, the discussions that followed with DMRI and the internal discussions held with the group of Australian representatives alone, four major conclusions were achieved:

- The concept of automating the process of boning striploins has significant benefits and it is worth pursuing. This was the underlaying assumption when the project was started, and the concepts discussed and tested during the visit to DMRI seemed to confirm this view.
- The tests witnessed in Denmark provided promising results and some level of confidence that the ultimate goal can be achieved, particularly when all the feedback from the first day turned into significant improved results on the second day

- However, the development of a fully automated striploin boning machine is not going to be a simple feat and it will be a long journey. Managing the risks and defining an exit strategy will be paramount to give collective resources a good use
- Despite the progress observed during the trials, the question about whether the Australian industry is getting value for money from DMRI in this development is a potential issue that needs to be addressed

Tests results showed that clamping and locking a striploin in place to allow an acceptable cut by mechanical means was a reasonable expectation. Solidly clamping the striploin is the corner stone to develop any machine, as it will allow keeping references in the different operations, and efficient and accurate cuts rely on a stable fixation. One of the reasons why DMRI was identified as an attractive developer for the Australian industry was the work they have done for pork and the concept they developed to position and secure pork middles, a very smart and elegant solution that dynamically straightens and clamps every piece, with only requiring placing the middles facing the machine on a conveyor belt. This project has shown the potential of an alternative concept DMRI has developed for beef backs, although it is quite a departure from the pork concept and significant more work will be required to automate it, currently relying on a manual locking process.

The concept of separating meat and featherbone with a linear cut was successfully demonstrated in the tests, where the support plate made a big difference in the second day. However, further work will be required to find the optimal configuration in terms angle of attack, blade design, trade off between compliance and actuator forces, etc.

The means of measuring and signing off on a result or task did not appear to be well managed by DMRI, as a result potential risks were not being identified or addressed. An example of this was the support plate (see Figure 22). Despite having tested at least 40 striploins in past tests, the first day trials were inconclusive to say the least, and a big contributing factor was the lack of support to fully secure the featherbone. Although the solution was proposed by DMRI engineers, it was not tested until we requested it, in the second day of trials and after a full day in between of work around the clock. A proper protocol to assess and validate test results should probably have indicated the support plate was required, being ready for the first day of tests.

Although the meetings after the tests included discussions about the operation to separate meat from the ribs, no related concept was demonstrated in this project. DMRI suggested the use of shaped knives, with 2 or more different units to separate/cut meat from ribs in 2 or more passes. The use of new materials like Vanax was considered but any work in that regard was left for the next phase.
Once agreed the development of this technology has significant benefits (with potential for 4 or more labour units to be saved), the biggest point of discussion before any recommendation is made going forward, is whether the Australian industry has obtained and will get value for money from DMRI.

The following points about the budget must be clarified:

- The total budget allocated to DMRI was 90% of the total
- The remaining 10% were used to cover Scott Technology involvement in the project and John Hughes' travel expenses. A Scott senior engineer (Brian Rekittke) was allocated part-time to this project to make the future technology transfer easier and be involved in discussions and trials in Denmark. John visited DMRI in November 09 for preliminary discussions and also attended the trials in May 10.

We were aware from the beginning of the difficulties and challenges of dealing with a research institute in Denmark, but DMRI's track record in developing successful technologies for the pork industry seemed to justify the need to contract their services. The distance is always a significant challenge to maintain communication and obtain continuous feedback from Australian processing experts. Our own experience has shown that even successful projects have suffered from that problem with NZ and Australian companies, with both categories considered 'local' providers compared to European developers. In this specific case with DMRI, we observed how just one day of face to face discussions provided significant feedback to quickly overcome some of the problems encountered in the first tests, something that can only be provided by strong project management reinforced with frequent face to face meetings if required.

5 Conclusions and recommendations

The recommendation made below is based on three fundamental underlaying assumptions:

1. The opportunity is worth pursuing and the Australian industry will benefit from a technology capable of automating or semi-automating the process of boning striploins, and in the future, longer sections of beef backs
2. DMRI has proven its capability to successfully develop automated systems for meat processing in pork, and so far the work done under this first stage has indicated they have the potential to offer interesting solutions for red meat
3. An element of concern exists about the value for money the Australian industry may obtain from this project if DMRI is not managed properly. The distance and the fact they have finally become just a researcher/developer and not a contributor to the project may not provide any powerful incentive for them to deliver results in a timely manner.

Additionally, it was already envisaged a technology transfer process should take place as early as possible. DMRI has never commercialised the technologies it develops, and that process has been handed over to companies like ATTEC in the past. When the current beef back boning project was conceived, RTL (or Scott Technologies for the same matter) was identified as the 'local' partner that would commercialise the technology in Australia. This choice has been reinforced with Scott Technology Australia recently establishing operations in Australia to better serve the Australian red meat industry.

Apart from a purely commercialization role, Scott should also help DMRI to develop a technology that meets Australian specifications. For this reason Scott has been involved in this first stage and should have a deeper involvement in the future, even sooner than expected, if we want to keep a tighter control on the development and make sure we achieve the desired results in the expected timeframe and within what is considered a reasonable budget.

Scott Technology Australia has a permanent presence in Europe with Luciano Schiavi, its Sales & Development manager based in Italy. Scott has offered Luciano to act as a local project manager while Stage 2 lasts, visiting DMRI no less than once every 8 weeks and monitoring progress, with reporting responsibilities to MLA and AMPC.

With all that in mind, Scott Technology Australia can be contracted to provide the following:

1. An ongoing frequent face to face project management service. This service is to be provided by Scott Euro with Luciano Schiavi who can physically meet with DMRI in Denmark as required.
2. A mechanical engineering input service. This service will continue to be provided by Brian Rekittke.
3. A commercialisation service. This service, to be provided by Scott Technology Australia, will review the developments as they progress and in conjunction with MLA determine the

most appropriate time for the financial investment to transfer from 100% Australian industry funding to 50% MLA funding and 50% (Scott/Australian processor) funding as part of the commercialisation transition/journey.

Stage 2

The following is recommended to the AMPC Technology committee:

- Use the budget tentatively allocated by AMPC for the next phase in the March 2010 committee meeting to continue the development in Stage 2, during 10/11, in order to achieve the promised benefits
- Assign Scott Technologies a more relevant role in Stage 2 to meet a double objective: managing DMRI and accelerating the technology transfer. As part of milestone 1 in Stage 2 Scott will define KPIs to evaluate project progress. These KPIs will be used in the Go/No Go points
- Engage John Hughes as Australian industry representative to provide processing guidance to DMRI and Scott and independently assess results, in particular on every Go/No Go point

DMRI will still be the main contractor, but Scott will have project management responsibilities. Scott will involve its resources in Australia, New Zealand and Europe to assist DMRI in the development process and monitor progress.

In order to provide the right incentives and obtain value for money, as well as reduce the financial burden for the Australian industry, MLA has asked Scott to become a funding partner in Stage 3, assuming some conditions (to be agreed between MLA and Scott) are met and objectives achieved in Stage 2.

If the AMPC Technology committee agrees to that, MLA and Scott will work on an MoU (Memorandum of Understanding) prior to a future Stage 3, that will outline the ‘rules of engagement’ with respect to Scott guaranteeing to take on the further development and commercialisation of the DMRI developments for the benefit of the Australian beef processing sector.

This MoU will outline the terms of Scott’s commitment to co-fund Stage 3 and commercialise the technology in the future. It is anticipated at this stage that the MoU will contain information about Key Performance Indicators, as well as market size, further development investment costs by Scott, and likely recommended retail price and resulting profit margin.

Based on compliance with KPIs during Stage 2, Scott will commit to further development and investment with co-funding and support by MLA (and AMPC if appropriate). If those KPIs are not met, then further discussions will need to take place between MLA and Scott to agree on a way forward.

Future development. Stage 3

If Stage 2 is successful the work bench will be shipped to Scott's workshop in Australia or New Zealand so that future development is undertaken here in Stage 3. In this case Scott would become the primary contractor and DMRI would provide design support.

Stage 2 will provide a technology platform to be developed following two different paths:

- A fully automated version, as initially conceived. The focus of this development is a striploin machine but if successful it will be extended to longer sections of the beef back as initially envisaged
- A manually assisted device, that will require manual operation but will in return provide minor labour savings, OH&S benefits or yield improvements (or a combination of the three) at a reduced capital cost. This development path will fit with Scott Technologies appointment as commercialiser of HookAssist and its strategy around intelligent assisted devices

It is estimated the automated route may require another $1M or more of further investment (Stage 3a and Stage 4) before we see a working prototype. The development of a manually assisted device should be a closer goal, and a working prototype could be fully developed in Stage 3b, for much less money than the automated system, if Stage 2 meets our expectations. In both cases, AMPC's future investment should be replaced partially or totally by Scott's.