final report

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Standalone Lamb Chine Bone Saw Australian Sales and Marketing Demonstration and Commercialisation Unit.

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Abstract

Over the past twelve years Meat and Livestock Australia and Scott Technology Australia (STA) have been developing solutions which align to a collective vision of an automated lamb boning room. As part of the lamb LEAP IV middle machine system a chine module has been developed. It is proposed that this chine module has the ability to be designed and configured as a standalone unit. After a preliminary independent cost benefit analysis by Greenleaf Enterprises it is apparent that a standalone offering would provide a significant return to the Australian processing sector above existing alternatives.

For processors with a low throughput, restricted floor space or have not got a capital budget that would allow a fully automated LEAP system it can result in modern technology not being adopted. The net result is that processing companies who process significant quantities of lamb have difficulty justifying installing equipment that increase the yield return of lamb, which in return reduces the maximum potential for producers to be paid more for lamb supplied.

Scott and MLA with the input from a range of Australian processors propose to design, build and trial a prototype standalone chine removal machine for lamb as a demonstration unit that can be used to evaluate the benefits achievable to different processing environments within Australia.

If successful, this concept would enable additional processing plants in Australia to adopt the equipment and it is anticipated that the machine would provide many of the benefits associated with the Scott Middle machine such as yield retention, reduction in labour, removal of a bandsaw task as well as make significant progress towards a fully automated LEAP middle machine. It is proposed that the adoption of the chine system will provide a stepping stone toward a fully automated solution where the inner workings of the machine will have hardware that can be redeployed and hence save on re-investment when making this move.

Executive summary

It has been proposed that the concept that underpins the chine module (developed as part of the Scott fully automated LEAP IV middle machine) could have the ability to be designed and configured as a standalone unit. A preliminary investigation by Greenleaf Enterprises shows that there is significant benefit achievable above and beyond current industry chine removal methods.

As a result Scott and MLA have proposed this project to develop a prototype standalone chine removal machine (based on the chine module concept) and to demonstration this machine at various processor sites within Australia as a series of 1 month trials to evaluate if the measured benefits relate to a one-off single processor or whether the current design can achieve the same benefit when installed (albeit for a short period of a month) in a variety of Australian processing facilities.

In this project the design, build and testing of a prototype standalone Lamb Chine Bone Saw (LCBS) has proven successful. Production trials of this machine as a demonstration unit have been completed at four trial/demonstration sites with trials lasting 1 month at each site sequentially. The trials evaluated the new design configuration to ensure it met all required Australian processing weight ranges and yield requirements.

Feedback from all four sites was overwhelmingly positive with demonstrated superior safety, yield, product presentation, throughput and sawdust reduction over current semi-automated machines and manual processes. Yield analysis confirmed the benefits that had been predicted were in fact significant and it was also found that as the chine machine returns a one piece chine and feather that this could become a saleable commodity as opposed to traditional methods that return this product to waste.

Some minor opportunities to improve the LCBS have been identified and resolutions are either already being implemented or are planned to be implemented with future machine builds. At each trial site, management and operational staff have expressed interest in the automated lamb processing systems offered by Scott Automation and Robotics either as a standalone chine machine or with further development as a chine plus flap and/or scribe machine.

It is concluded that trailing of this kind of equipment has significant benefit to processors in evaluating solutions for adoption.

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1 Background

Over the past twelve years Meat and Livestock Australia and Scott have been developing solutions which align to a collective vision of an automated lamb boning room. The solutions consist of an x-ray machine, a primal cutting machine, a middle machine, a forequarter system and hindquarter system (currently under development for Australian customers). As part of the middle machine system a chine module has been developed.

It has been proposed that this chine module could have the ability to be designed and configured as a standalone unit.

An independent analysis previously completed by Greenleaf Enterprises identified a cost benefit analysis of the chinning systems on offer by BLM and Scott with the Scott system having a 0.18% yield loss and the BLM system a 0.51% yield loss, with this difference equating to $0.85 per head processed.

As a result Scott and MLA would like to evaluate, and hence understand further, if this value is a one-off single processor benefit or whether the current design can achieve the same benefit when installed in a variety of Australian processing facilities.

This project will develop a Standalone Lamb Chine Boning prototype machine that will be trialled for 1 month (sequentially) at each of four Australian meat processing companies. The trials will evaluate and test the new design configuration to ensure it meets all required Australian processing weight ranges and yield requirements. Scott Technology will also evaluate if the yield value, based on a single site evaluation, is achieved when installed in a variety of Australian processing facilities. The project will identify if the system is ready for facilitated adoption or commercial sale; or if additional R&D is required to suit the variation of product and specifications found across Australian processing industry. The outcome will provide an investment option for plants not able to afford a full automation solution, and also provide performance, reliability and value-engineering input into chine boning to be delivered to the Australian processing sector

2 Project objectives

Scott and MLA will develop an Australian standalone Lamb Chine Bone Saw (LCBS) sales and marketing demonstration and commercialisation unit. This unit will be designed and optimised to process a full range of Australian lamb rack products. The unit will then be trialled at (at least) five Australian processing sites to demonstrate the safety, yield, throughput and cut quality advantages over current manual and semi-automated techniques.

The project has nine milestones with the following high level objectives:

Milestone 1	Review a wider range of Australian specifications. The milestone report is to detail the outcomes of the review.
Milestone 2	Design and build a Standalone Lamb Chine Bone Saw. The milestone report should include any problems encountered during the design and build process.
Milestone 3	FAT and shipment. The milestone report will include details of the FAT process and results.
Milestone 4	Conduct production trials at site 1. The milestone report and video should detail any learnings and feedback that result from the site commissioning and trial.
Milestone 5	Conduct production trials at site 2.
Milestone 6	Conduct production trials at site 3.
Milestone 7	Conduct production trials at site 4.
Milestone 8	Conduct production trials at site 5.

3 Methodology and Results

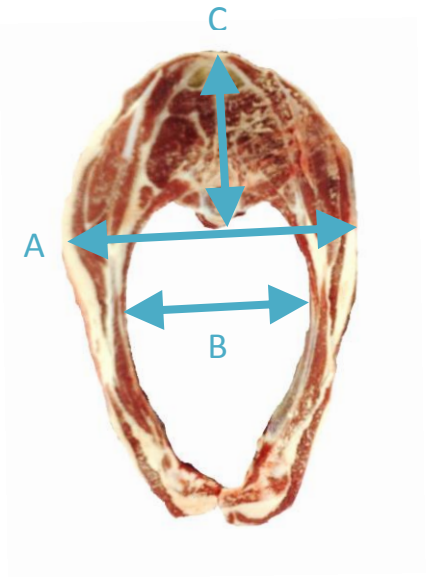
3.1 Trial setup

Seven lamb processing sites were contacted and registered their interest to participate. These sites are listed below:

- Processor #1
- *Processor #2*
- Processor #3
- Processor #4
- Processor #5
- Processor #6
- Processor #7

Product being processed at these sites varied in dressed carcass weight (entering the boning floor) from 15.7kg to 35kg. Across the seven participating sites, a total of 2,676 measurements were taken from 669 racks.

Four key measurements were identified as being critical for high yield processing of racks. The first three measurements (A, B & C) are shown in the image below. The fourth measurement (D), was the overall length of the rack along the spine.



Results for the four key dimensions across the seven sites are shown in the table below.

	Dimension A	Dimension B	Dimension C	Dimension D
Minimum (mm)	147	93	84	138
Average (mm)	192	117	104	205
Maximum (mm)	284	154	133	297

Product variability as a ratio (largest measured / smallest measured) at each site (and for all sites) is shown in the table below.

	Dimension A	Dimension B	Dimension C	Dimension D
All Sites	1.93	1.66	1.58	2.15
Processor #1	1.46	1.33	1.34	1.41
Processor #5	1.54	1.51	1.33	1.33
Processor #6	1.47	1.45	1.51	1.36
Processor #4	1.25	1.26	1.31	1.46
Processor #3	1.38	1.46	1.24	1.23
Processor #7	1.58	1.47	1.34	1.32
Processor #2	1.51	1.47	1.52	1.45

The data collected from the seven participating sites has revealed that there is significant dimensional variability in Australian lamb from which rack products are being produced. The standalone lamb chine bone saw will be designed to achieve high yield results across the full spectrum of Australian lamb rack products. The unit should be trialled at sites across Australia to demonstrate the yield improvements and other benefits to processors.

3.2 Build trial machine

Using the data and feedback collected from the seven Australian processors that participated in the site survey and experience garnered from thousands of hours of operation of the Scott Technology Automated Lamb Middle Boning System, the standalone LCBS has been designed to achieve high yield results across the full spectrum of Australian lamb rack products.

Improved safety is another cornerstone of the design. Immediate safety benefits have been derived from making the operator remote from the actual sawing and slicing operation and the unit's enclosed design helps protect everyone from moving parts and unexpected bone chips.

The quality of the cut and final product is expected to be a significant improvement over other semi-automated offerings as the LCBS uses circular saws and circular knives to cleanly remove the product from the bone. By contrast, one of the most common chine off machines currently found on sites across Australia tears the product from the bone, which negatively impacts yield and product presentation.

Some processors have highlighted limited throughput capacity of their current semi-automated solutions as a bottleneck in their process. The LCBS uses a conveyor infeed that allows processing of up to 12 products per minute, this throughput rate should meet the needs of the vast majority of processors. In fact this throughput rate can be increased further, but the limiting factor (apart from product availability) becomes the ability of the operator to load the product fast enough.

Rework Conducted During the Build

During the build process, the following redesign and rework was conducted:

- Various conveyor rollers required redesign and replacement to allow smoother and easier operation of the extendable conveyors.
- Some rework to various moving parts was conducted to simplify the build and future maintenance.
- Several pneumatic systems and mounts were modified to improve access and simplify maintenance.
- Numerous minor adjustments to parts due to error accumulation or insufficient design tolerance were required to accurately place precision components, most critically the blade alignment tool.
- Various upgrades to motors, pneumatics, electronics, fitting, glands etc. to reduce risk of water ingress and improve water drainage.
- Some in-house modifications to purchased pneumatic clamps were required to allow them to perform as desired.
- Some in-house modifications to the motors were required to allow them to perform as desired, including replacement of non stainless steel parts.

- Motor layout, mounting and cable reticulation changes were required to accommodate for motors that did not match the drawings provided.
- Minor changes to polly-carbonate shielding to improve its coverage, strength and machine access were conducted.

Visiting seven Australian processors during the data collection and consultation phase of this project yielded valuable insight into the challenges processors are facing with their chine off process. This has driven modifications to the design that will improve compatibility with local product and bring the machine closer in line with processor needs and expectations. The design and build process has taken longer than originally gazetted. However, the additional time and resources invested during this phase will help reduce the rework that will be required during Factory Acceptance Trials and on-site production trials.

The Lamb Chine Bone Saw has the potential to improve the safety, yield, product quality and throughput of the chine off process over current manual and semi-automated techniques. The design and build process was completed successfully and the unit was ready to begin factory acceptance trials.

3.3 Factory testing

The factory acceptance trials involved processing a total of twelve (12) saddles. During the first few product test runs, the following deficiencies were identified:

1. During normal operation, the operator loads the saddle onto the product infeed conveyor and as the product enters the machine enclosure a set of product guide rails secures it in the correct orientation. Early tests found that some products would slip out of position before they reached the product guide rails. This would result in a non-symmetric cut if the featherbones didn't find their way between the upper cutting blades. This is what occurred during product trial 3, shown in the Figure 1 below. A video of product trial 3 has been provided.

Figure 1: LCBS Product Trial 3 Result (Fail)

To resolve this, a second set of product guide rails was installed at an earlier point on the product infeed conveyor, outside of the machine enclosure. This modification had the secondary benefit of providing the operator with another reference surface to ensure correct product loading. The CAD model of this modification is identified as item 1 in Figure 2 overleaf.

2. There was a gap under the lower blades which could impinge and/or scuff passing product as it passed. This same gap was also identified as a cleaning hazard. This issue was identified during product trials 7 and 8.

Plastic inserts that closely follow the contours of the blades and surrounding surfaces were manufactured to close gaps at the bottom of the blades. The location and general shape of the plastic insert is identified as item 2 in Figure 2 below.

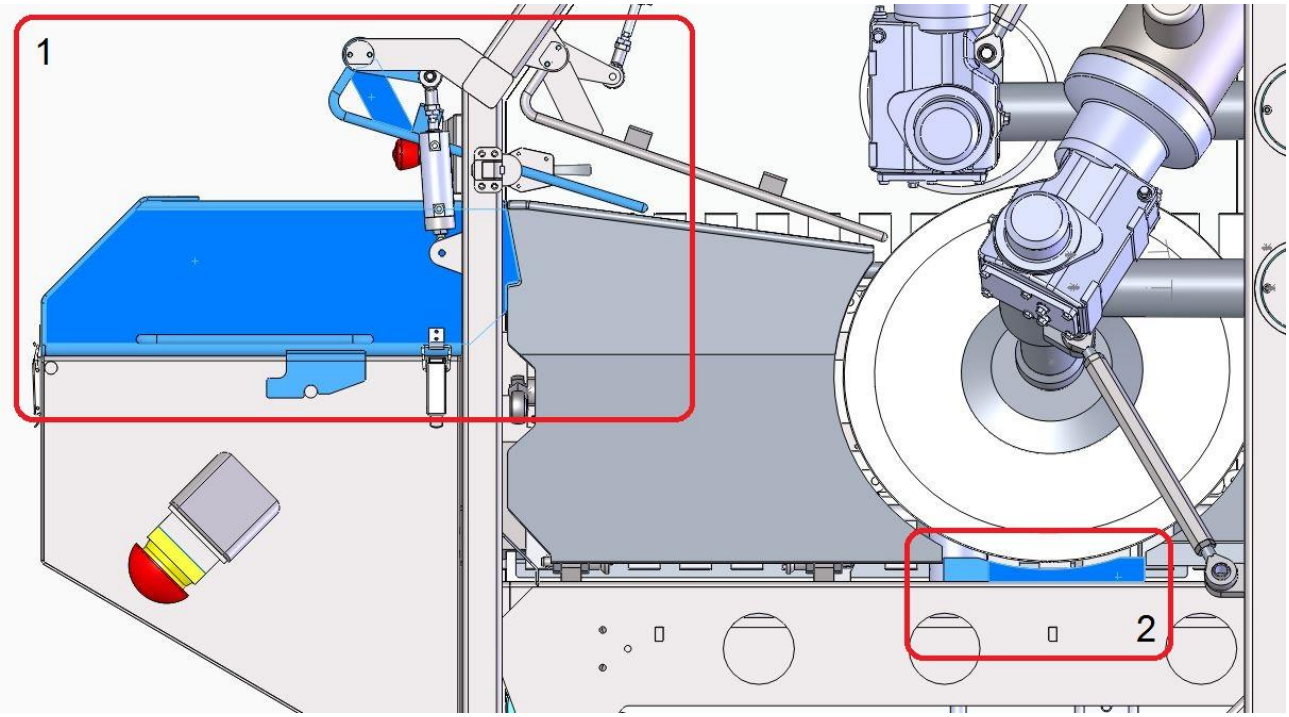


Figure 2: Modifications to LCBS following FATs

Since successfully completing FATs the LCBS has been packed up and is currently being shipped to Australia.

Videos of every product run were recorded and pictures of the final processed products are shown over the next few pages.

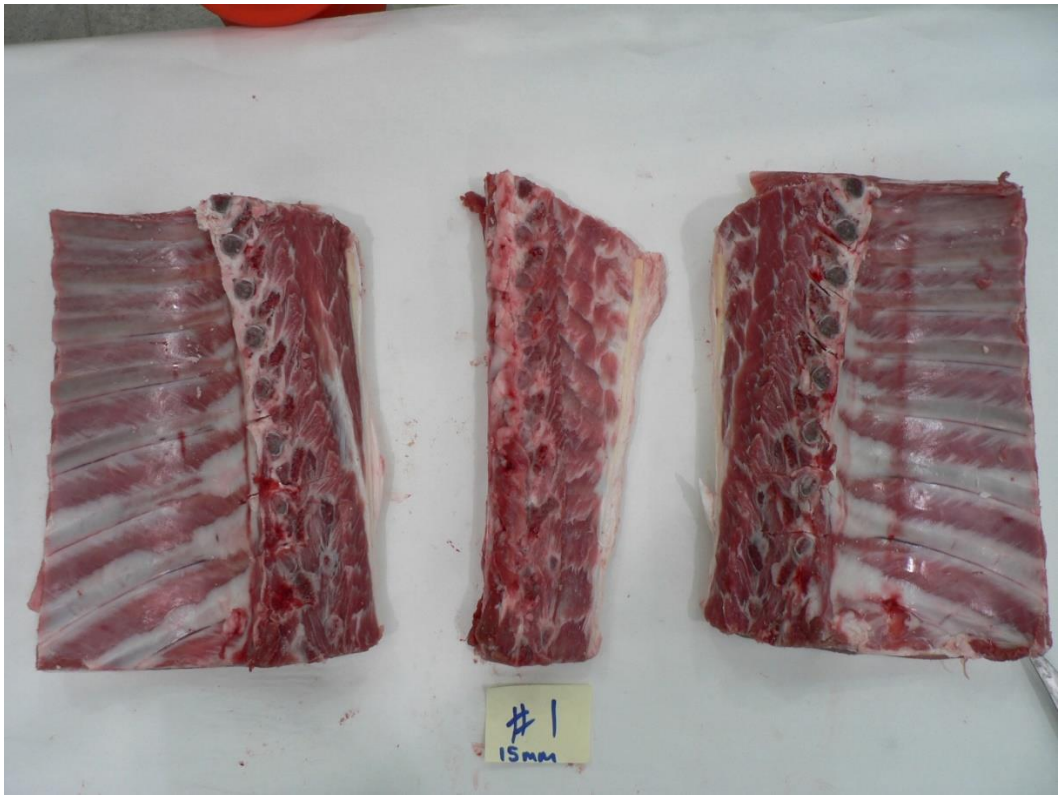


Figure 3: LCBS Product Trial 1 Result

Figure 4: LCBS Product Trial 2 Result

Figure 5: LCBS Product Trial 4 Result

Figure 6: LCBS Product Trial 5 Result

Figure 7: LCBS Product Trial 6 Result

Figure 8: LCBS Product Trial 7 Result

Figure 9: LCBS Product Trial 8 Result

Figure 10: LCBS Product Trial 9 Result

Figure 11: LCBS Product Trial 10 Result

Figure 12: LCBS Product Trial 11 Result

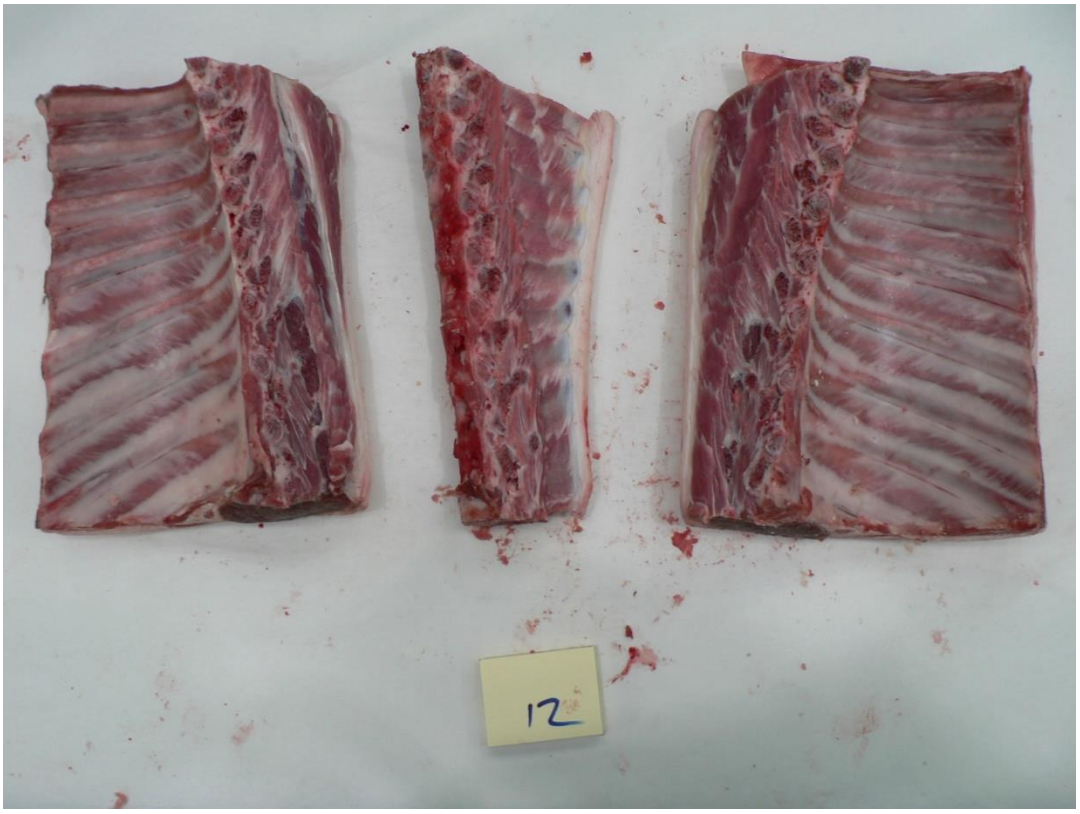


Figure 13: LCBS Product Trial 12 Result

The factory acceptance tests have proven to be a valuable exercise as two improvements to the machine have been identified and installed. This will assist in making positive first impressions to the processor during the first production trials.

The LCBS was shipped directly to its first trial site at Processor #2 where it arrived in mid-June. Engineers from the design, manufacture and FAT stages were present to conduct SATs and provide support to address any unforeseen issues during the first stages of full production trials.

3.4 Trial site 1

The first production trial of the LCBS was successfully completed at Processor #2. The unit was installed and commissioned on site without incident and feedback from the site has been overwhelmingly positive. Discussions with site reveal that they consider the LCBS to be superior to their existing CFO machine in all aspects, including: yield, cut quality, saw dust reduction, throughput and reliability. Show below in Figure 14 and Figure 15 are example CFO racks (and bones) processed by the LCBS.

Figure 14: Example CFO Racks processed by the LCBS

Figure 15: Example Chine/feather Bones extracted by the LCBS

The site had, in previous months, trialled an ATTEC machine which featured both CFO and flap off capabilities. Site management explained that the ATTEC offering had not met their yield expectations for the CFO process, but that the LCBS had exceeded their expectations. However, the ability to conduct repeatable flap removal was a significant advantage as accurate flap cut length is critical to achieving high overall yield. Therefore, the site communicated that, in its current configuration (lacking flap off capability), the LCBS is not yet a viable option to support their process.

Buoyed by the performance of the LCBS, site management has been actively enquiring into opportunities to introduce a more comprehensive standalone lamb middle processing machine into their process. With the first priority being the addition of flap off functionality.

3.4.1 Improvements conducted and observations made during trials at site 1

A number of modifications designed to improve the LCBS's performance were implemented during the trial period. These included:

Identified Issue	Resolution Enacted
The cutting edge on the two upper blades degraded very rapidly after only a few product passes. This was due to an excessively sharp blade cutting angle.	The blade shape was modified to increase the longevity of the blade while still achieving the desired cutting depth into the product.
Some product was being damaged as it passed the lower blades while on the product discharge conveyor.	An additional blade guard was added which reduced these occurrences significantly. (Figure 16)
The replaceable product pusher inserts (Figure 17) were being worn away by the product and machine blades.	The inserts were modified so that they were reversible, thereby granting two uses out of the one insert. (Figure 18) Further design revision is underway.
Excessive fat and other remnants on the inside of the spine were interfering with the proper operation of the product chain conveyor. (Figure 19)	A "Spine Scraper" was integrated into the loading station (Figure 20). The removal of this excess fat allows for more consistent placement of the cutting blades on the rack.
The rod lock, which locks the position of the product relative to the cutting blades, was activating later than anticipated.	The rod lock sensor was moved to force an earlier rod lock activation. (Figure 21)
The loading station cover was slightly off centre to the product chain conveyor. This increased the opportunity for products to be pushed through the cutting blades off centre, resulting in a failed cut and/or damaged pushers.	A large shim was added to realign the loading station, and a locating pin and slot was integrated into the loading station cover. (Figure 22)
The air and electrical services exited onto the floor, despite most supplies typically being located overhead.	The electrical and air services were redirected to exit near the top of the machine. (Figure 23)
There was the opportunity for an individual to reach inside the machine via the product discharge conveyor. This presented a hazard.	An additional guard that covered the product discharge conveyor was added. (Figure 24)
Warm product was tested in the machine, and the results were not acceptable.	Product specification was updated, product must be at most 5°C to be processed in the LCBS.
The rails that guide the product conveyor chain allowed some out of axis movement. This was contributing to the product pusher damage.	The product conveyor chain rails were shimmed to a closer tolerance. Thereby improving product pusher rigidity and reducing occurrences of damage to the pushers.

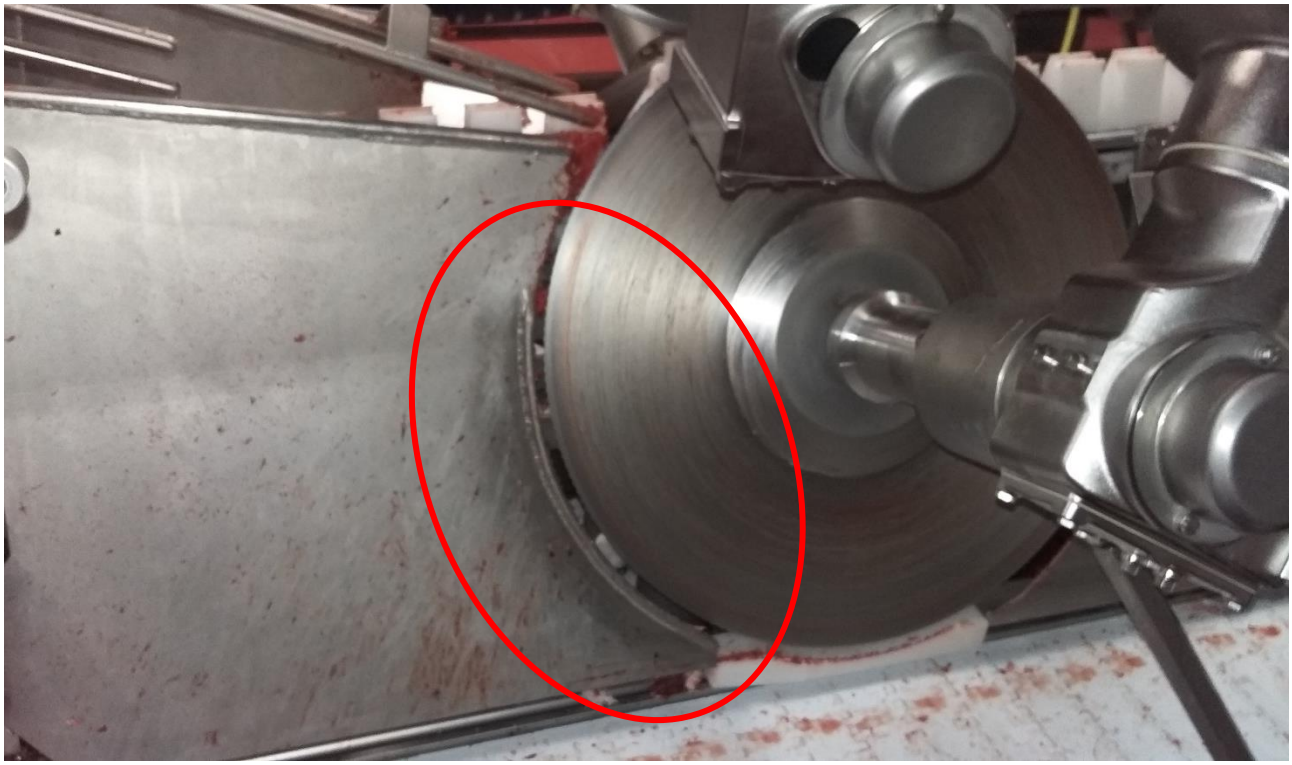


Figure 16: Additional blade guard

Figure 17: Replaceable product pusher inserts come into close proximity of cutting blades

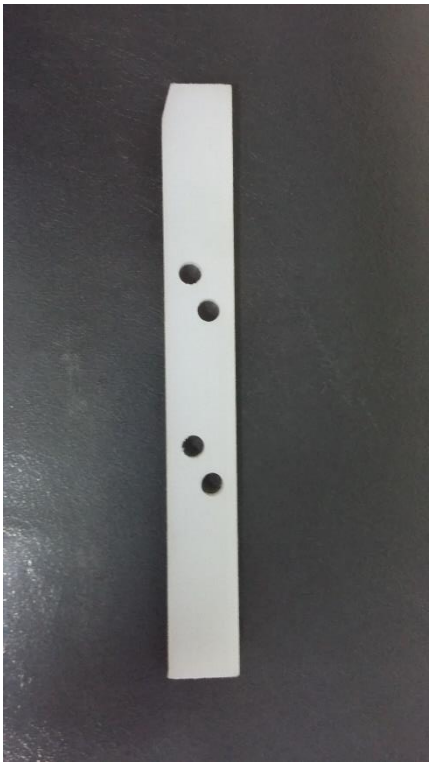


Figure 18: Modified reversible pusher

Figure 19: Excessive fat and other remnants on the rack spine

Figure 20: Spine scrapper installed onto loading station

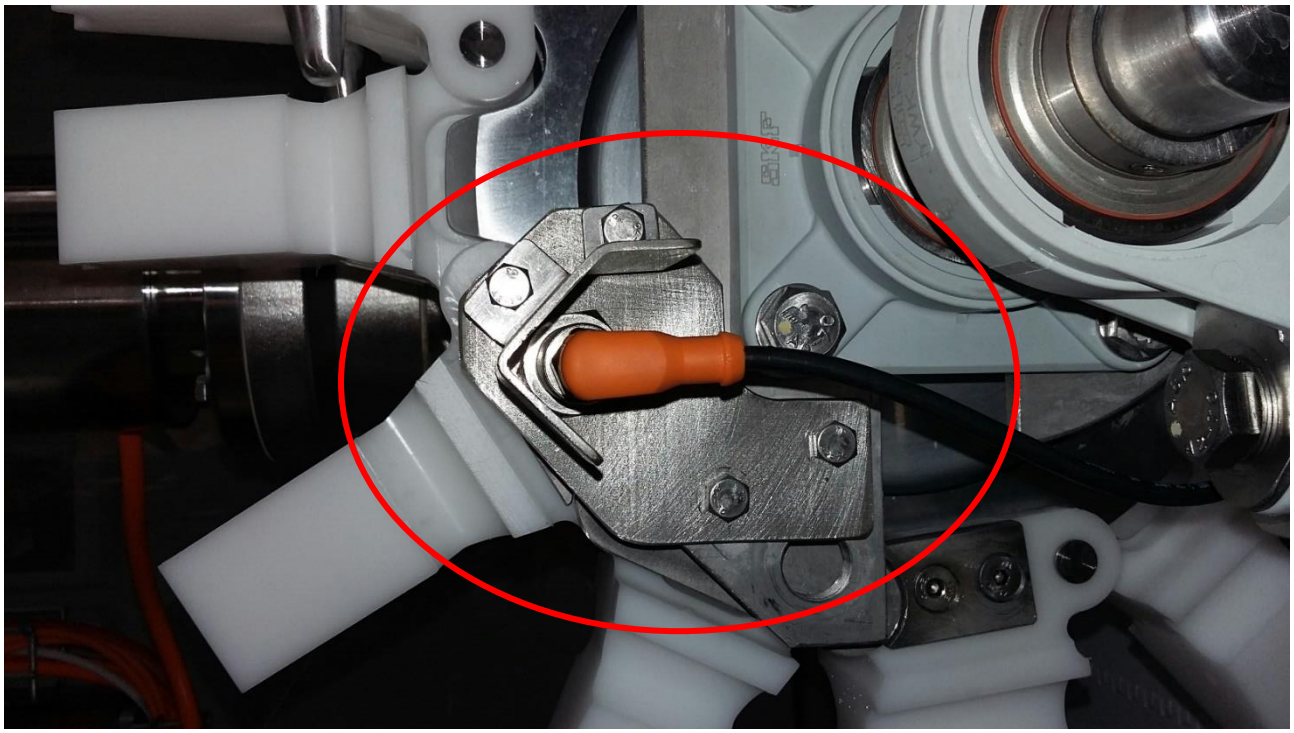


Figure 21: Repositioned rod-lock sensor (image rotated)

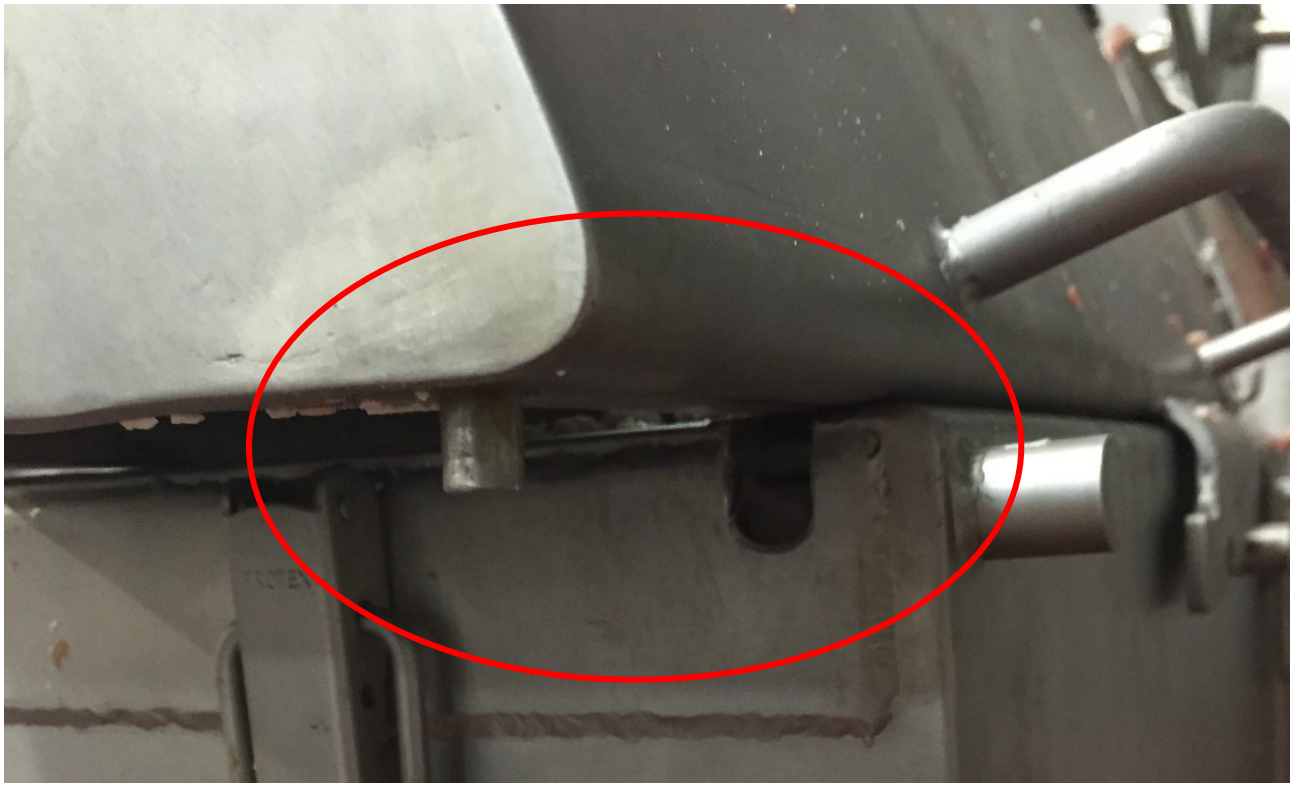


Figure 22: Product loading station with new locating pin and slot

Figure 23: Power supply now enters machine near the top

Figure 24: Additional guarding at end of product discharge conveyor

3.4.2 Modifications considered

There were a number of issues identified during the trial which are being considered for further action.

Identified Issue	Options being considered
At its default settings, the LCBS is running at about double the speed of the rest of the room (12ppm). This throughput rate is not easily adjustable by the site.	The throughput rate may be made programmable. However, there may not be any advantage to this.
Quality control staff mentioned that the product pushers that are being worn down during production would be introducing an undetectable contaminant into the product or waste.	Continue to revise the design to reduce the occurrence of damage to the pushers. Modify the material of the pushers so they are x-ray (or otherwise) detectible.
One of the product conveyor chain links that houses a product pusher became chipped.	The design or material of this component should be revised to prevent this from reoccurring.
The LCBS was very difficult to transport in tight spaces.	Easily detachable castor wheels should be fabricated. These should be capable of being installed and removed from the frame without external assistance (forklift).
The mounting points on the rail that guides the product chain are few and far between. This results in a lack of support and rigidity in the product chain.	A future revision of the machine should include more of these mounting points at critical areas like the product loading station, and as close to the circular saws as possible.
The configuration of the rod eye (Figure 25) near the product loading station that helps locate the product chain horizontally, forces the chain to rotate and move out of axis slightly whenever it is deflected by product. This affects the location of the cuts on the product and can contribute to failed products and yield loss.	A redesign of this feature to balance out the forces and resulting deflection in the product chain as it is deflected downwards is required.
After the rack is processed, the extracted chine/feather bone has to balance on the product chain until it is ejected onto the outfeed conveyor. Sometimes the chine/feather bone falls off of this chain too early and lands/mixes with the product. This can cause an inconvenience for processors down the line.	Guards should be installed to prevent this mixing at both the chain and outfeed conveyor locations. However, there is a risk of inadvertently creating a snag problem within the machine, especially for any product that is not correctly processed/separated by the blades.
The product and bone outfeed conveyors all exit along the same line (Figure 26). This makes it difficult to keeping the parts separate for transport (via a secondary conveyor) to the product and waste belts.	Future machines may have to have their product outfeed conveyor design customised to meet site requirements. A staggered outfeed conveyor would make sorting and transport of parts easier in some situations. There is no reason why a secondary conveyor couldn't be part of the same offering.
Cleaning the machine is difficult and time consuming. In particular, the product chain sprockets requires that the machine be stopped, opened, sprayed, closed and started multiple times to be able to properly clean.	A targeted "self-cleaning" capability could be introduced to facilitate easier cleaning of more difficult components. These could be as simple as correctly placed access holes (possible hazard) or external plugs that feed appropriately located internal spray fittings.

Figure 25: Rod eye that controls the horizontal position of the product chain - Needs revision

Figure 26: Product (Left and Right) and Bone (Middle) conveyors, all exit along the same line

The Installation and production trials at the first site revealed a number of areas of improvement for the machine. Many of these have already been implemented, some are in the process of being so, but others can only feasibly be introduced into the next build of this class of machine.

The first trial site was very impressed with the LCBS. The machine has undoubtedly achieved its goal of safe, high yield and high throughput chine and feather removal from lamb racks. Site management continues to engage the developers of the LCBS to investigate opportunities to incorporate additional functionality into the stand alone machine, with accurate integrated rack flap removal being the first priority.

The LCBS has been in production at the first trial site for four (4) weeks and is now ready to be dispatched to the second trial site.

Given the high level of processor interest observed during earlier stages of this project and the overwhelmingly positive feedback from the first demonstration of the Lamb Chine Bone Saw, it was recommended that the unit be permitted to continue onto the second demonstration site.

3.5 Trial site 2

The second production trial of the LCBS has been successfully completed at Processor #7. This site currently processes their CFO racks by hand on bandsaws. Floor supervisors immediately recognised the improved operator safety that the LCBS offers and initial reactions to the consistency of yield, improved product presentation, increased throughput potential and reduced bandsaw dust were also positive. Site management has engaged the LCBS developers to investigate opportunities to incorporate integrated flap off and cap scribe functionality into the offering.

3.5.1 Opportunities to Improve the LCBS from trials at site 2

Identified Issue	Resolution
There is a small gap at the interface between the loading station cover and the product pusher chain covers. This gap can be a snag point on certain product with very narrow ribs, as can be seen in Figure 30 below. This snag point can push the product out of alignment while on the product pusher chain and result in a failed cut.	Operators are now trained to push the product beyond this snag point when loading. This does not have a significantly negative impact on throughput. When at a suitable workshop, this gap should be modified/softened to prevent any opportunity for the product to snag.

Figure 27: Gap at interface of loading station cover and product pusher chain cover is a snag point

Identified Issue	Resolution
Operators have suggested making the pusher link in the product pusher chain a different colour to the rest of the chain. This would help make the actual pusher easier to identify.	The pusher inserts and pusher links are already being considered for a change in material that is both more detectable and more pliable to avoid chips/snapping. Changes to the colour should also be considered.

The conveyor belt that ejects the product after processing is too small for some of the largest product. This problem is exacerbated by some of the door guarding and other structures in the path of the conveyor as can be seen in Figure 28 below. At present the operator has to stop the machine and clear the obstruction manually.	Modifications to the path can be made to help guide large product down the conveyor. However, ultimately the conveyor itself will have to be improved in some way, either by making it wider or perhaps experimenting with added ribs or paddles.

Figure 28: Large products are becoming stuck on the small conveyor

Identified Issue	Resolution
One of the risks to the operator is becoming caught on the product pusher chain. The product entry point is too small for someone to be pulled into the machine, but an arm could certainly be pulled in and	There are already 4 E-Stops on the LCBS, 2 of which are within easy reach from the loading station. However, an E-Stop bar placed at the product entry point would automatically be pushed by someone

even if the blades can't be reached an injury could still occur.	being pulled into the machine, this could potentially reduce the severity of any injuries. This would be an added safety feature in excess of any requirements, but is still worth considering.
The gaps at the interfaces between the large circular blades and product pusher chain covers, particularly at the ejection end of the machine represent a snag point. Product can become snagged here, but also become damaged due to continued uncontrolled contact with the saw, as seen in Figure 29 below.	Additional material could be added to the product pusher chain covers to reduce the gaps. Ideally, the covers would be expanded to shield product from the entire bottom section of the circular blades.

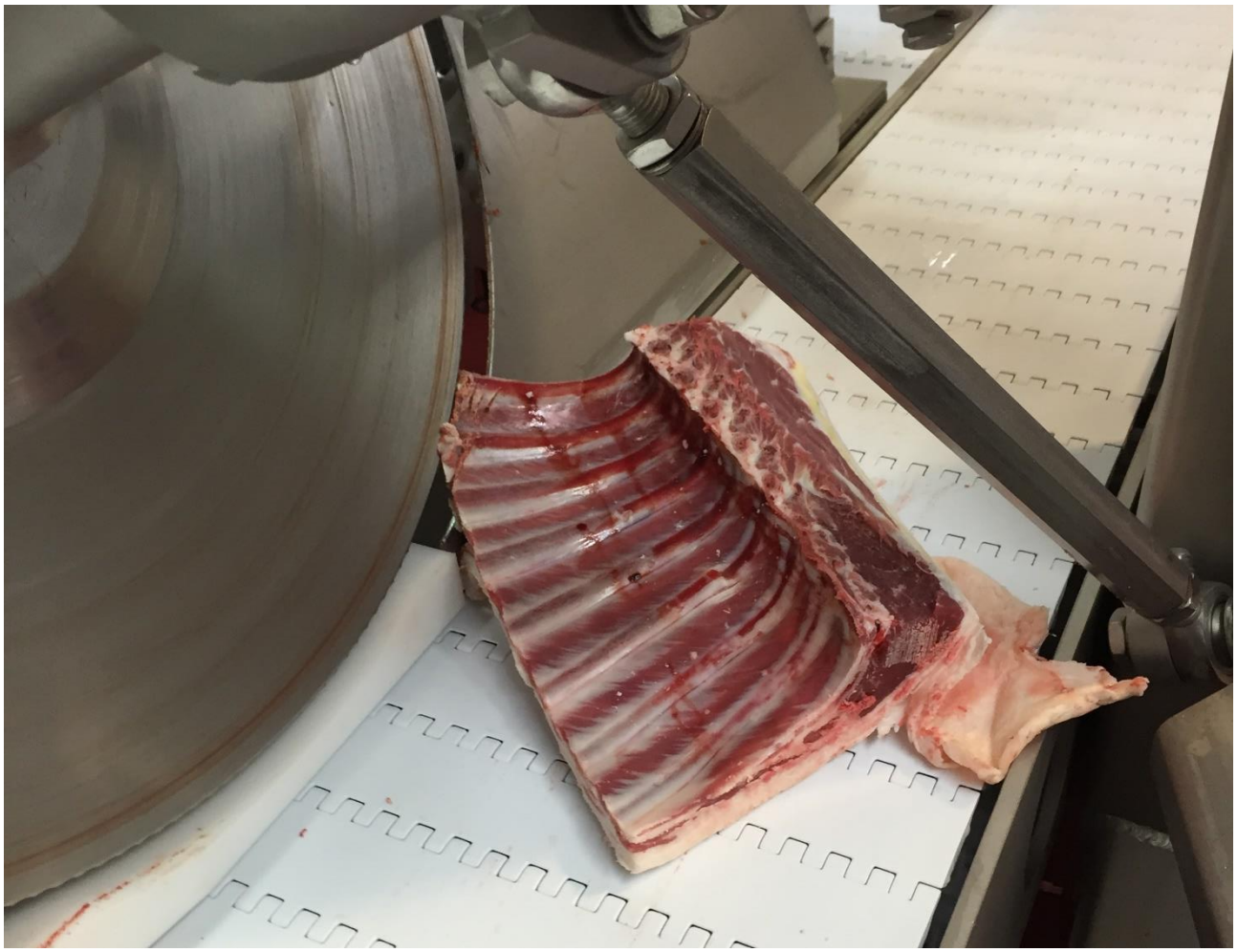


Figure 29: Gaps at interface between large circular blades and product pusher chain covers are a snag point

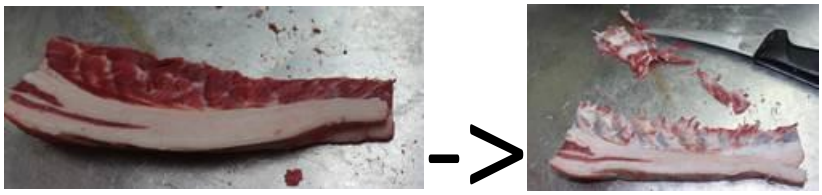
3.5.2 Yield Trials

A trial was conducted where a range of product was processed manually and automatically to identify any improvement in yield. The below outlines the test method for the trial.

Manual Process

Lean remaining was scraped off each half chine and a weight determined (2 per carcass) is shown below

Lean remaining was scraped off each feather bone set and a weight determined (2 per carcass) is shown below



Average grams due to saw blade loss from soft siding (2 per carcass) was calculated

Auto Process

Lean remaining on chine and feather bone set was scraped off and an weight measured (grams)

The measurement of lean remaining on the bone for approximately 150 bandsaw processed CFO racks was recorded. This process was repeated for product processed by the LCBS. These measurements gave an average value for unrecovered yield from each process:

- Weight in grams per carcass for the manual bandsaw process, and
- Weight in grams per carcass for the LCBS process.

This equates to an average yield increase (improvement) well in excess of what was expected from yield retention estimates per carcass when processing with the LCBS.

The installation and production trials revealed opportunities to improve the LCBS. Some of these opportunities had already been capitalised on, while others required a significant amount of rework to the machine. All improvements were recorded so to be incorporated into the design of new builds of the machine.

The LCBS had been well received at all trial sites so far. All sites were showing interest in either the LCBS itself, or a further developed version thereof.

The LCBS successfully completed four (4) weeks of production trials at the second trial site and was shipped to conduct trials at a third site.

Given the high level of processor interest during all stages of the project thus far and the overwhelmingly positive feedback from the first two demonstrations, it was recommended that the project be permitted to continue.

3.6 Trial site 3

The third production trial of the LCBS had been successfully completed. The site traditionally processes their CFO racks by hand on a bandsaw. Floor supervisors immediately recognised the improved operator safety that the LCBS offers and initial reactions to the consistency of yield, improved product presentation, increased throughput potential and reduced bandsaw dust were all positive. Site management had expressed interest in ordering a LCBS with integrated flap off and/or cap scribe functionality.

3.6.1 Identified Improvement Opportunities During Trials at Site 3

Identified Issue	Resolution Progress
During this most recent site trial, the machine was prevented from starting due to a door safety interlock issue. The issue was resolved by on-site maintenance staff under direction from Scott engineers.	RESOLVED. One of the door safety interlocks "forgot" its counterpart and had to be "re-taught" a new counterpart. The issue has not resurfaced since. Further action will be required if this issue arises again.
The trial site has reported back that all the pusher inserts including the replacements have been expended. However, they continued to use the machine with the worn down inserts and did not reported any increase in failed cuts nor any reductions in overall yield.	REQUIRES EXPERIMENTATION. The constant replacement of the pusher inserts may be causing more trouble that they are worth. Modified pushers will be experimented with during the next trial.

3.6.2 Progress of Previously Identified Improvement Opportunities

Identified Issue	Resolution Progress
The cutting edge on the two upper blades degraded very rapidly after only a few product passes. This was due to an excessively sharp blade cutting edge.	RESOLVED. The blade shape was modified to increase the longevity of the blade while still achieving the desired cutting depth into the product. These blades are sharpened at the start of each trial.
Excessive fat and other remnants on the inside of the spine were interfering with the proper operation of the product chain conveyor.	RESOLVED. A "Spine Scraper" was integrated into the loading station. The removal of this excess fat allows for more consistent placement of the cutting blades on the rack. This issue is not repeated at every site.
The rod lock, which locks the position of the product relative to the cutting blades, was activating later than anticipated.	RESOLVED. The rod lock sensor was moved to force an earlier rod lock activation.
The loading station cover was slightly off centre to the product chain conveyor. This increased the opportunity for products to be pushed through the cutting blades off centre, resulting in a failed cut and/or damaged pushers.	RESOLVED. A large shim was added to realign the loading station, and a locating pin and slot was integrated into the loading station cover.

Identified Issue	Resolution Progress
The air and electrical services exited onto the floor, despite most supplies typically being located overhead.	RESOLVED. The electrical and air services were redirected to exit near the top of the machine.
There was the opportunity for an individual to reach inside the machine via the product discharge conveyor. This presented a hazard.	RESOLVED. An additional guard that covered the product discharge conveyor was added.
Warm product was tested in the machine, and the results were not acceptable.	RESOLVED. Product specification was updated, product must be at most 5°C to be processed in the LCBS.
The rails that guide the product conveyor chain allowed some out of axis movement. This was contributing to the product pusher damage.	RESOLVED. The product conveyor chain rails were shimmed to a closer tolerance. Thereby improving product pusher rigidity and reducing occurrences of damage to the pushers.
One of the product conveyor chain links that houses a product pusher became chipped.	RESOLVED. Plans to modify the pusher insert should resolve this issue.
At its default settings, the LCBS runs at about double the speed of the some of the boning rooms being trialled at. This throughput rate is not easily adjustable by the site.	NO ACTION REQ. There is currently no plan to make the throughput rate adjustable by the operator.
After a rack is processed, the extracted chine/feather bone balances on the product chain until it is ejected onto the outfeed conveyor. Sometimes the chine/feather bone falls off of this chain too early and mixes with the rack product. This can cause an inconvenience for processors down the line.	NO ACTION REQ. It has been decided that for now, the risk of creating an unnecessary snag point outweighs the inconvenience of occasionally dropping a chine onto the rack conveyor.
The replaceable product pusher inserts are worn away over time.	PARTIALLY RESOLVED. The inserts were modified so that they were reversible, thereby granting two uses out of the one insert. New long term solutions are being investigated.
Operators have requested that we make the product pushers easier to see, additionally quality control staff would like the pusher inserts to be easily detectable.	PARTIALLY RESOLVED. Inquiries have been made into upgrading the pusher inserts to a (blue coloured) metal detectable plastic. However, given the small order qty and lack of availability of suitable material, material costs are extremely prohibitive at this stage. It will most likely be worth having the parts made in bulk in the US. For now, replacement inserts will be manufactured from a more readily available blue plastic.
The LCBS is very difficult to transport in tight spaces.	FUTURE CONSIDERATION. Easily detachable castor wheels should be developed. These should be capable of being installed and removed from the frame without external assistance (forklift).

Identified Issue	Resolution Progress
Cleaning the machine is difficult and time consuming. In particular, cleaning the product chain sprockets requires that the machine be stopped, opened, sprayed, closed and started multiple times to be able to properly clean.	PENDING UPGRADE. Feedback directly from the cleaners at recent trial sites has been positive, the machine is easier to clean than first anticipated, particularly given its size and complexity. That being said, the integration of targeted "self-cleaning" capability to facilitate easier cleaning of some areas would still be advantageous.
The conveyor belt that ejects the product after processing is too small for some of the largest product. This problem is exacerbated by some of the door guarding and other structures in the path of the conveyor. At present the operator has to stop the machine and clear the obstruction manually.	PENDING UPGRADE. When at a suitable workshop, modifications to the path can be made to help guide large product down the conveyor. Future builds will have upgraded conveyors that are either wider and/or use ribs or paddles to encourage the movement of product.
Despite earlier modifications that partially resolved this issue, the gaps around the large circular blades still cause some snags and damage to product.	PENDING UPGRADE. When at a suitable workshop, additional guarding will be added reduce the gaps. Future builds will most likely have covers that completely shield product from the entire bottom section of the circular blades.
The mounting points on the rail that guides the product chain are few and far between. This results in a lack of support and rigidity in the product chain.	FUTURE BUILDS. Future builds of the machine will include more of these mounting points at critical areas, such as the product loading station and the circular saws.
The configuration of the rod eye near the product loading station that helps locate the product chain horizontally, forces the chain to rotate and move out of axis slightly whenever it is deflected by product. This affects the location of the cuts on the product and can contribute to failed products and yield loss.	FUTURE BUILDS. Revisions to the rod eye configuration will be investigated during the next build.
One of the risks to the operator is becoming caught on the product pusher chain. The product entry point is too small for someone to be pulled into the machine, but an arm could potentially be pulled in and even if the blades can't be reached an injury could still occur.	FUTURE BUILDS. There are already 4 E-Stops on the LCBS, 2 of which are within easy reach from the loading station. However, an E-Stop bar placed across or around the product entry point would "automatically" be pushed by someone being pulled into the machine, this could potentially reduce the severity of any injuries. Implementation is not being considered for the existing unit but could be incorporated into a future build as an added safety feature.
The product and bone outfeed conveyors all exit along the same line. This makes it difficult to keeping the parts separate during transport (via a secondary conveyor) to the product and waste belts.	FUTURE BUILDS. Future builds will have to have their product outfeed conveyor design customised to meet site requirements. A staggered outfeed conveyor would make sorting and transport of parts easier in some situations. A secondary conveyor could be integrated into any offering.

Identified Issue	Resolution Progress
The small gap shown in Figure 30 below can be a snag point on certain product with very narrow ribs. This snag point can push the product out of alignment and result in a failed cut.	PARTIAL RESOLUTION. Operators are now trained to load the product beyond this snag point. This does not have a significant impact on throughput. PENDING UPGRADE. When at a suitable workshop, this gap will be modified to prevent any opportunity for the product to snag.

Figure 30: Gap at interface of loading station cover and product pusher chain cover is a snag point

3.6.3 Yield Trials

Initial feedback from the third trial site regarding yield was very promising. Two separate preliminary analyses were conducted by site staff, with the following results given:

1. Completed cartons of Frenched racks (containing 16 racks each) were said to be weighing in with more than expected yield based on the yield retention of the LCBS.
2. CFO racks (Before Cap-of and Frenching) were weighing in at greater than expected.

The two methods yielded very similar results to total saleable weight increase and therefore appear to validate each other.

The LCBS had been well received at all trial sites thus far. All sites had shown interest in either the LCBS itself, or a further developed version thereof.

An arrangement with the current trial site had been reached whereby the site could continue to use the machine during an extended trial period and in return the LCBS development team is permitted on site to film in-production footage that would feature in a promotional video.

The LCBS was at this point also shipped to participate in the MLA Annual General Meeting in November. Therefore the next on-site trial was delayed until late November.

The installation and production trials to that point had revealed opportunities to improve the LCBS. Some of these opportunities had already been capitalised on, while others required a significant amount of rework to the machine. All improvements are recorded so that they can be incorporated into new builds of the machine.

Given the high level of processor interest during all stages of this project to this point and the overwhelmingly positive feedback from the first three on-site trials, it was recommended that the project be permitted to continue to the next trial site.

3.7 Trial site 4

3.7.1 Site Feedback

The fourth (4th) trial site demonstration of the LCBS has been successfully completed at Processor #8. This site traditionally processes their CFO racks on a modified but aging BLM chine off machine. Floor supervisors immediately recognised the improved operator safety that the LCBS offers and reactions to the increased yield, improved product presentation, increased throughput potential and reduced bandsaw dust were all positive. Site management expressed interest in ordering a LCBS with integrated flap off and split functionality, particularly if it can be integrated into their plans for future automation. During the demonstration visit, site supervisors requested a presentation (to include the plant manager) be shown that introduced their team to current and upcoming automated lamb processing technologies.

3.7.2 Identified Improvement Opportunities During Trials at Site 4

Identified Issue	Resolution Progress
During this demonstration the LCBS was trialled with worn down pusher inserts to assess the impacts this has on production (Figure 31). It was determined that worn down pushers do increase the risk of failed cuts.	IN PROGRESS. An entirely new pusher chain and pusher insert configuration has been designed (Figure 32). When completed, this new product pusher system can be installed while the machine is on-site.
The cutting edge of one of the top (feather) circular knives has been chipped (Figure 33). After investigation it was found that this sort of damage has not been seen on other similar knives on similar systems and so is likely due to incorrect or incorrectly loaded product.	IN PROGRESS. The damaged blade will be replaced. If the damage reoccurs, further investigation will be required.

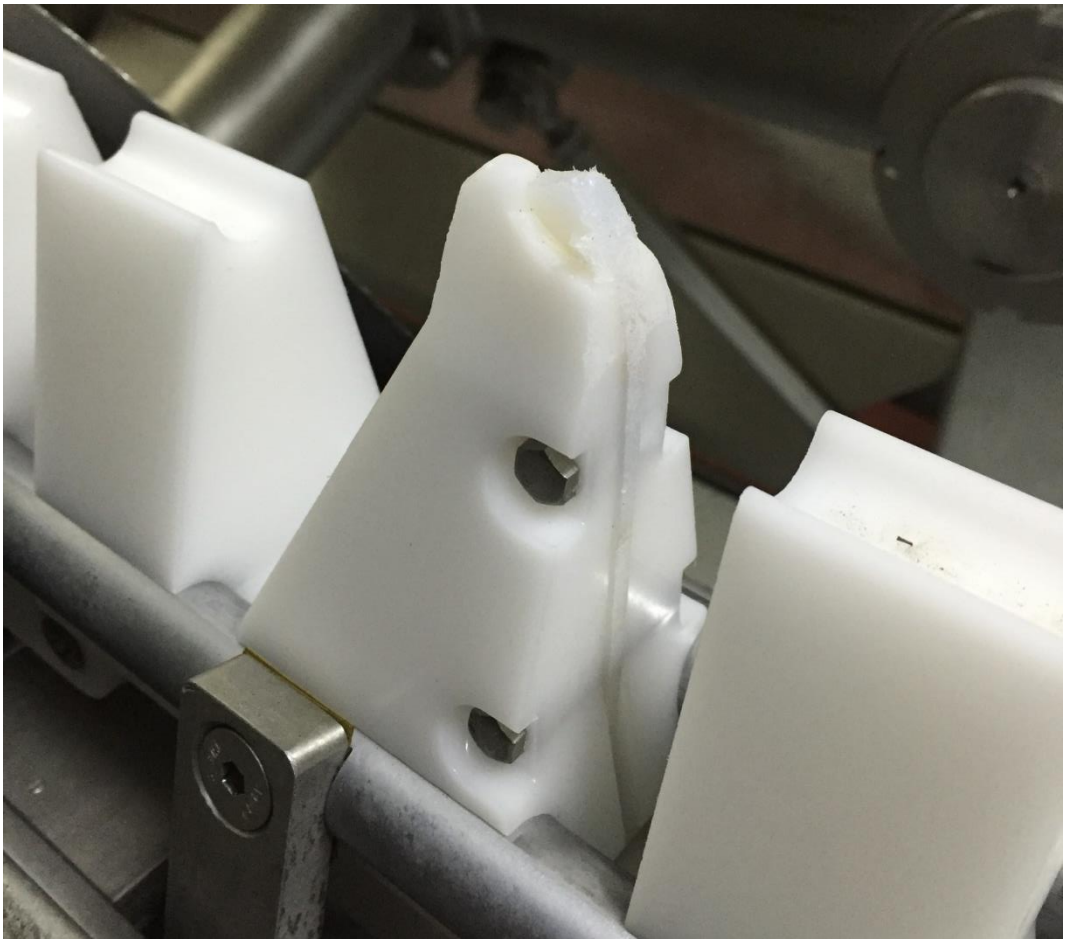


Figure 31: Worn down product pusher and wear insert

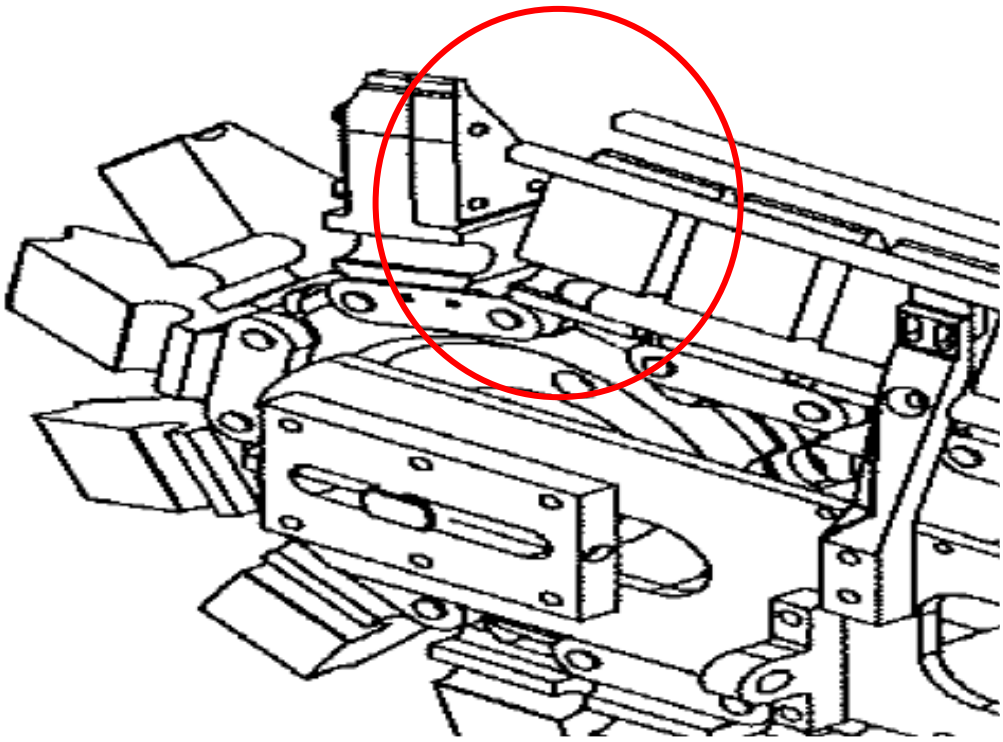


Figure 32: Redesigned product pusher and wear attachment

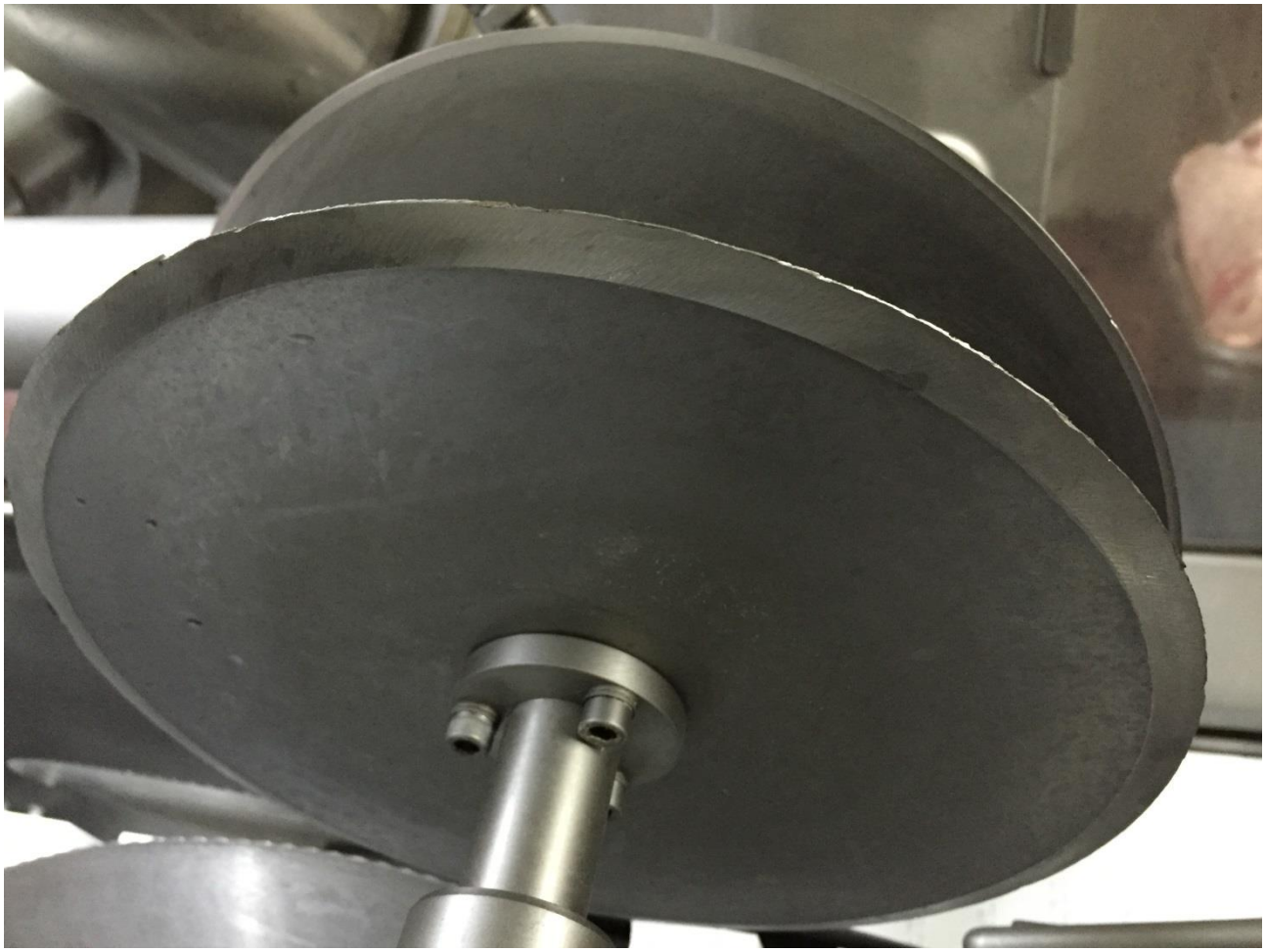


Figure 33: Chipped top (feather) circular knife

3.7.3 Yield Trials

Initial feedback from the site regarding yield was promising. Although at least 2 independent (conducted by different site supervisors) yield trials were being conducted during the demonstration, feedback from only 1 of these site driven yield analyses was shared with the visiting Scott Engineer. The results of this yield analysis are shown below:

- CFO racks pairs processed on the LCBS left more than expected weight increase on the racks than the benchmark value for similar product.
- It was estimated that the site produces up to 13,000 CFO rack pairs per week.
- CFO Racks (Frenched and capped) can be valued at wholesale prices.

Therefore it can be estimated that the value of increased yield is far in excess of what was expected. This yield increase is considerably lower than previous sites. This may because this site has modified their existing BLM, but also because CFO racks seem to make up less than 50% of their current production (the remainder being spilt racks and whole saddles). If the site received more orders for CFO racks, then the value that the LCBS would contribute would increase correspondingly.

The LCBS had been well received at all demonstration sites to this point. All sites had shown interest in either the LCBS itself, or a further developed version thereof.

The installation and production trials to this point had revealed opportunities to improve the LCBS. Some of these opportunities had already been capitalised on, some were in the process of being implemented, others were flagged to be implemented if/when this machine underwent a refit, while a few require a significant rebuild and will most likely only be incorporated into future builds of machines of this type.

Given the high level of processor interest during all stages of this project and the overwhelmingly positive feedback from the first four (4) on-site trials/demonstrations, it is recommended that the project be permitted to continue onto the next milestone.

3.8 Trial site 5

3.8.1 Cancelled

Before trial site 5 was scheduled to commence MLA and Scott reached an agreement to allow this chine machine to be used as an input to another MLA project for the development of a flap station addition for the standalone chine. The machine was used at a processor facility to enable the chine and flap development to occur.

As such the trial site 5 had to be cancelled as the project was to run past the completion date for this trial project.

4 Discussion

4.1 Trial site 1

A number of areas of improvement for the machine were identified at site 1. Many of these have were implemented, some are in the process of being so, but others can only feasibly be introduced into the next build of this class of machine.

Site operational and management staff were very impressed with the LCBS. The machine achieved its goal of safe, high yield and high throughput chine and feather removal from lamb racks. Site management continues to engage Scott to investigate opportunities to incorporate additional functionality into the stand alone machine, with accurate integrated rack flap removal being the first priority.

4.2 Trial site 2

The measurement of lean remaining on the bone for approximately 150 bandsaw processed CFO racks was recorded. This process was repeated for product processed by the LCBS. These measurements gave an average value for unrecovered yield from each process that equates to an average yield increase (improvement) in excess of what was expected when processing with the LCBS.

4.3 Trial site 3

Two separate analyses were conducted by staff from site 3, with the following results given:

1. Completed cartons of Frenched racks (containing 16 racks each) were said to be weighing in more than expected from predicted yield retention.
2. CFO racks (Before Cap-of and Frenching) were weighed and showed a yield retention of more than expected.

The two methods yielded very similar results to total saleable weight increase and therefore appear to validate each other.

4.4 Trial site 4

Site operational and management staff conveyed that the system had excellent yield recovery.

At least 2 independent (conducted by different site supervisors) yield trials were performed during the demonstration, feedback from only 1 of these site driven yield analyses was shared with the visiting Scott Engineer. The results of this yield analysis are shown below:

- CFO racks pairs processed on the LCBS left showed significantly more weight on the racks than the benchmark value for similar product.
- It was estimated that the site produces up to 13,000 CFO rack pairs per week.
- CFO Racks (Frenched and capped) can be valued at typical wholesale prices.

Therefore it can be estimated that the value of increased yield is well within the expected range. This yield increase is lower than previous sites. This may because this site has modified their existing BLM, but also because CFO racks seem to make up less than 50% of their current production (the remainder being spilt racks and whole saddles). If the site received more orders for CFO racks, then the value that the LCBS would contribute would increase correspondingly. The yield retention is still very good compared to the existing machinery.

4.5 Chine machine developed and built

A standalone lamb chine bone machine was constructed using the principals that underpin the Scott LEAP IV chine module. The lamb chine machine was built and commissioned successfully.

The machine was designed using data collected from seven participating facilities representing a good cross section of lamb product processed in Australia. As such the design improves compatibility with local product and brings the machine closer in line with processor needs and expectations.

The standalone LCBS was designed to achieve high yield results across the full spectrum of Australian lamb rack products. The design also focused on improved safety, product quality and throughput of the chine off process over current manual and semi-automated techniques.

Additionally, the quality of the cut and final product is a significant improvement over other semi-automated offerings as the LCBS uses circular saws and circular knives to cleanly remove the product from the bone. By contrast, one of the most common chine off machines currently found on sites across Australia tears the product from the bone, which negatively impacts yield and product presentation.

A resulting standalone manually loaded lamb chine machine was designed and built and has successfully passed Factory Acceptance Trials and on-site production trials.

4.6 Chine machine improvements

Both from the series of factory acceptance trials completed at the Scott factory as well as trialling the lamb chine machine at a range of processors has enabled issues that are particular to certain ranges of product to be unearthed and addressed. Many of the issues were able to be addressed at the time of trialling through on-site modifications while other modifications will require further design and will be incorporated into the next builds of the machine.

A comprehensive list of issues can be found in Appendix A.

5 Conclusions and Recommendations

This project developed a Standalone Lamb Chine Boning prototype machine that was trialled for 1 month (sequentially) at each of four Australian meat processing companies. The trials evaluated and verified that the new design configuration was able to meet all required Australian processing weight ranges and yield requirements for lamb with an opportunity identified for extending this to mutton.

In concluding this project the following has been completed albeit with one trial site excluded.

1. A standalone manually loaded chine removal machine has been designed and built using
    a. The concepts that underpin the LEAP IV middle machine.
    b. A range of product data and processor feedback received from seven participating sites.
2. This standalone chine machine has been trialled at four processor site with positive feedback
    a. Measurements have shown at least 25 grams and up to 62.5 grams additional yield retention over existing processes in these plants.
    b. The machine demonstrates benefits in product quality, WHS and throughput
    c. The chine machine returns a one piece chine and feather which becomes a saleable commodity as opposed to traditional methods that return this product to waste.
3. There have been a range of improvements made and further improvements identified during the trialling process that will enhance the machines capability and effectiveness when delivered to other processing facilities.
4. Each of the trial sites have substantiated interest in either a standalone chine or a standalone chine further developed to incorporate flap and/or scribe functionality.
5. The final trial site was cancelled to enable the machine to become an input into the development of a flap and chine machine under an additional MLA sponsored project.

It was found that similar (and better) results were achieved than initially predicted and is was also found that the nett benefits for each site situation depended on a number of site specific variables for example; throughput, manual process, existing equipment and marketable product value (including for the one piece chine and feather).

Given the interest and positive feedback that has been received in relation to the trials it is highly recommended that the remaining issues be addressed and where there is an opportunity to further trial the system at additional sites that this be considered.

Trialling technology such as the lamb chine machine at sites offers a range of benefits including:

1. Providing processors with a hands on appreciation of the capability of the machinery
2. Providing the processor with an opportunity to evaluate the nett benefits that are specific to their process and product
3. Exposes the machinery to a wider range of products and processes which in turn allows the machine to be improved to perform for this full range.
4. Having the machine run under a trial environment enables a good level of scrutiny and independent analysis to be completed which processors find easier to believe as opposed to a study done on a machine in another plant.

For these reasons it is highly recommended that this style of trial be considered for other pieces of equipment and as an excellent method of progressing commercialisation as part of the development of standalone manually loaded machinery.

The project has also confirmed that the system is ready for facilitated adoption or commercial sale whilst additional R&D could be pursued to suit the variation of product and specifications found across Australian processing industry to include mutton and lamb if desirable.

The standalone lamb chine machine provides an investment option for plants not able to afford a full automation solution to provide the performance, reliability and value-engineering input into chine boning that the Scott chining concept can deliver.

6 Bibliography

Philip Green – Greenleaf Enterprises PL, 2014. *Lamb chining technology comparison – final report*. MLA A.TEC.0104.

7 Appendix A – List of all issues

Identified Issue	Resolution Enacted
The cutting edge on the two upper blades degraded very rapidly after only a few product passes. This was due to an excessively sharp blade cutting angle.	The blade shape was modified to increase the longevity of the blade while still achieving the desired cutting depth into the product.
Some product was being damaged as it passed the lower blades while on the product discharge conveyor.	An additional blade guard was added which reduced these occurrences significantly.
The replaceable product pusher inserts were being worn away by the product and machine blades.	The inserts were modified so that they were reversible, thereby granting two uses out of the one insert. Further design revision is underway.
Excessive fat and other remnants on the inside of the spine were interfering with the proper operation of the product chain conveyor.	A "Spine Scraper" was integrated into the loading station. The removal of this excess fat allows for more consistent placement of the cutting blades on the rack.
The rod lock, which locks the position of the product relative to the cutting blades, was activating later than anticipated.	The rod lock sensor was moved to force an earlier rod lock activation.
The loading station cover was slightly off centre to the product chain conveyor. This increased the opportunity for products to be pushed through the cutting blades off centre, resulting in a failed cut and/or damaged pushers.	A large shim was added to realign the loading station, and a locating pin and slot was integrated into the loading station cover.
The air and electrical services exited onto the floor, despite most supplies typically being located overhead.	The electrical and air services were redirected to exit near the top of the machine.
There was the opportunity for an individual to reach inside the machine via the product discharge conveyor. This presented a hazard.	An additional guard that covered the product discharge conveyor was added.
Warm product was tested in the machine, and the results were not acceptable.	Product specification was updated, product must be at most 5°C to be processed in the LCBS.
The rails that guide the product conveyor chain allowed some out of axis movement. This was contributing to the product pusher damage.	The product conveyor chain rails were shimmed to a closer tolerance. Thereby improving product pusher rigidity and reducing occurrences of damage to the pushers.
At its default settings, the LCBS is running at about double the speed of the rest of the room (12ppm). This throughput rate is not easily adjustable by the site.	The throughput rate may be made programmable. However, there may not be any advantage to this.
Quality control staff mentioned that the product pushers that are being worn down during production would be introducing an undetectable contaminant into the product or waste.	Continue to revise the design to reduce the occurrence of damage to the pushers. Modify the material of the pushers so they are x-ray (or otherwise) detectible.
One of the product conveyor chain links that houses a product pusher became chipped.	The design or material of this component should be revised to prevent this from reoccurring.
The LCBS was very difficult to transport in tight spaces.	Easily detachable castor wheels should be fabricated. These should be capable of being installed and removed from the frame without external assistance (forklift).
The mounting points on the rail that guides the product chain are few and far between. This results in a lack of support and rigidity in the product chain.	A future revision of the machine should include more of these mounting points at critical areas like the product loading station, and as close to the circular saws as possible.

The configuration of the rod eye near the product loading station that helps locate the product chain horizontally, forces the chain to rotate and move out of axis slightly whenever it is deflected by product. This affects the location of the cuts on the product and can contribute to failed products and yield loss.	A redesign of this feature to balance out the forces and resulting deflection in the product chain as it is deflected downwards is required.
After the rack is processed, the extracted chine/feather bone has to balance on the product chain until it is ejected onto the outfeed conveyor. Sometimes the chine/feather bone falls off of this chain too early and lands/mixes with the product. This can cause an inconvenience for processors down the line.	Guards should be installed to prevent this mixing at both the chain and outfeed conveyor locations. However, there is a risk of inadvertently creating a snag problem within the machine, especially for any product that is not correctly processed/separated by the blades.
The product and bone outfeed conveyors all exit along the same line. This makes it difficult to keeping the parts separate for transport (via a secondary conveyor) to the product and waste belts.	Future machines may have to have their product outfeed conveyor design customised to meet site requirements. A staggered outfeed conveyor would make sorting and transport of parts easier in some situations. There is no reason why a secondary conveyor couldn't be part of the same offering.
Cleaning the machine is difficult and time consuming. In particular, the product chain sprockets requires that the machine be stopped, opened, sprayed, closed and started multiple times to be able to properly clean.	A targeted "self-cleaning" capability could be introduced to facilitate easier cleaning of more difficult components. These could be as simple as correctly placed access holes (possible hazard) or external plugs that feed appropriately located internal spray fittings.
There is a small gap at the interface between the loading station cover and the product pusher chain covers. This gap can be a snag point on certain product with very narrow ribs. This snag point can push the product out of alignment while on the product pusher chain and result in a failed cut.	Operators are now trained to push the product beyond this snag point when loading. This does not have a significantly negative impact on throughput. When at a suitable workshop, this gap should be modified/softened to prevent any opportunity for the product to snag.
Operators have suggested making the pusher link in the product pusher chain a different colour to the rest of the chain. This would help make the actual pusher easier to identify.	The pusher inserts and pusher links are already being considered for a change in material that is both more detectable and more pliable to avoid chips/snapping. Changes to the colour should also be considered.
The conveyor belt that ejects the product after processing is too small for some of the largest product. This problem is exacerbated by some of the door guarding and other structures in the path of the conveyor. At present the operator has to stop the machine and clear the obstruction manually.	Modifications to the path can be made to help guide large product down the conveyor. However, ultimately the conveyor itself will have to be improved in some way, either by making it wider or perhaps experimenting with added ribs or paddles.
One of the risks to the operator is becoming caught on the product pusher chain. The product entry point is too small for someone to be pulled into the machine, but an arm could certainly be pulled in and even if the blades can't be reached an injury could still occur.	There are already 4 E-Stops on the LCBS, 2 of which are within easy reach from the loading station. However, an E-Stop bar placed at the product entry point would automatically be pushed by someone being pulled into the machine, this could potentially reduce the severity of any injuries. This would be an added safety feature in excess of any requirements, but is still worth considering.

The gaps at the interfaces between the large circular blades and product pusher chain covers, particularly at the ejection end of the machine represent a snag point. Product can become snagged here, but also become damaged due to continued uncontrolled contact with the saw.	Additional material could be added to the product pusher chain covers to reduce the gaps. Ideally, the covers would be expanded to shield product from the entire bottom section of the circular blades.

During this most recent site trial, the machine was prevented from starting due to a door safety interlock issue. The issue was resolved by on-site maintenance staff under direction from Scott engineers.	RESOLVED. One of the door safety interlocks "forgot" its counterpart and had to be "re-taught" a new counterpart. The issue has not resurfaced since. Further action will be required if this issue arises again.
The trial site has reported back that all the pusher inserts including the replacements have been expended. However, they continued to use the machine with the worn down inserts and did not reported any increase in failed cuts nor any reductions in overall yield.	REQUIRES EXPERIMENTATION. The constant replacement of the pusher inserts may be causing more trouble that they are worth. Modified pushers will be experimented with during the next trial.
The cutting edge on the two upper blades degraded very rapidly after only a few product passes. This was due to an excessively sharp blade cutting edge.	RESOLVED. The blade shape was modified to increase the longevity of the blade while still achieving the desired cutting depth into the product. These blades are sharpened at the start of each trial.
Excessive fat and other remnants on the inside of the spine were interfering with the proper operation of the product chain conveyor.	RESOLVED. A "Spine Scraper" was integrated into the loading station. The removal of this excess fat allows for more consistent placement of the cutting blades on the rack. This issue is not repeated at every site.
The rod lock, which locks the position of the product relative to the cutting blades, was activating later than anticipated.	RESOLVED. The rod lock sensor was moved to force an earlier rod lock activation.
The loading station cover was slightly off centre to the product chain conveyor. This increased the opportunity for products to be pushed through the cutting blades off centre, resulting in a failed cut and/or damaged pushers.	RESOLVED. A large shim was added to realign the loading station, and a locating pin and slot was integrated into the loading station cover.
The air and electrical services exited onto the floor, despite most supplies typically being located overhead.	RESOLVED. The electrical and air services were redirected to exit near the top of the machine.
There was the opportunity for an individual to reach inside the machine via the product discharge conveyor. This presented a hazard.	RESOLVED. An additional guard that covered the product discharge conveyor was added.
Warm product was tested in the machine, and the results were not acceptable.	RESOLVED. Product specification was updated, product must be at most 5°C to be processed in the LCBS.
The rails that guide the product conveyor chain allowed some out of axis movement. This was contributing to the product pusher damage.	RESOLVED. The product conveyor chain rails were shimmed to a closer tolerance. Thereby improving product pusher rigidity and reducing occurrences of damage to the pushers.
One of the product conveyor chain links that houses a product pusher became chipped.	RESOLVED. Plans to modify the pusher insert should resolve this issue.

At its default settings, the LCBS runs at about double the speed of the some of the boning rooms being trialled at. This throughput rate is not easily adjustable by the site.	NO ACTION REQ. There is currently no plan to make the throughput rate adjustable by the operator.
After a rack is processed, the extracted chine/feather bone balances on the product chain until it is ejected onto the outfeed conveyor. Sometimes the chine/feather bone falls off of this chain too early and mixes with the rack product. This can cause an inconvenience for processors down the line.	NO ACTION REQ. It has been decided that for now, the risk of creating an unnecessary snag point outweighs the inconvenience of occasionally dropping a chine onto the rack conveyor.
The replaceable product pusher inserts are worn away over time.	PARTIALLY RESOLVED. The inserts were modified so that they were reversible, thereby granting two uses out of the one insert. New long term solutions are being investigated.
Operators have requested that we make the product pushers easier to see, additionally quality control staff would like the pusher inserts to be easily detectable.	PARTIALLY RESOLVED. Inquiries have been made into upgrading the pusher inserts to a (blue coloured) metal detectable plastic. However, given the small order qty and lack of availability of suitable material, material costs are extremely prohibitive at this stage. It will most likely be worth having the parts made in bulk in the US. For now, replacement inserts will be manufactured from a more readily available blue plastic.
The LCBS is very difficult to transport in tight spaces.	FUTURE CONSIDERATION. Easily detachable castor wheels should be developed. These should be capable of being installed and removed from the frame without external assistance (forklift).
Cleaning the machine is difficult and time consuming. In particular, cleaning the product chain sprockets requires that the machine be stopped, opened, sprayed, closed and started multiple times to be able to properly clean.	PENDING UPGRADE. Feedback directly from the cleaners at recent trial sites has been positive, the machine is easier to clean than first anticipated, particularly given its size and complexity. That being said, the integration of targeted “self-cleaning” capability to facilitate easier cleaning of some areas would still be advantageous.
The conveyor belt that ejects the product after processing is too small for some of the largest product. This problem is exacerbated by some of the door guarding and other structures in the path of the conveyor. At present the operator has to stop the machine and clear the obstruction manually.	PENDING UPGRADE. When at a suitable workshop, modifications to the path can be made to help guide large product down the conveyor. Future builds will have upgraded conveyors that are either wider and/or use ribs or paddles to encourage the movement of product.
Despite earlier modifications that partially resolved this issue, the gaps around the large circular blades still cause some snags and damage to product.	PENDING UPGRADE. When at a suitable workshop, additional guarding will be added reduce the gaps. Future builds will most likely have covers that completely shield product from the entire bottom section of the circular blades.

The mounting points on the rail that guides the product chain are few and far between. This results in a lack of support and rigidity in the product chain.	FUTURE BUILDS. Future builds of the machine will include more of these mounting points at critical areas, such as the product loading station and the circular saws.
The configuration of the rod eye near the product loading station that helps locate the product chain horizontally, forces the chain to rotate and move out of axis slightly whenever it is deflected by product. This affects the location of the cuts on the product and can contribute to failed products and yield loss.	FUTURE BUILDS. Revisions to the rod eye configuration will be investigated during the next build.
One of the risks to the operator is becoming caught on the product pusher chain. The product entry point is too small for someone to be pulled into the machine, but an arm could potentially be pulled in and even if the blades can't be reached an injury could still occur.	FUTURE BUILDS. There are already 4 E-Stops on the LCBS, 2 of which are within easy reach from the loading station. However, an E-Stop bar placed across or around the product entry point would "automatically" be pushed by someone being pulled into the machine, this could potentially reduce the severity of any injuries. Implementation is not being considered for the existing unit but could be incorporated into a future build as an added safety feature.
The product and bone outfeed conveyors all exit along the same line. This makes it difficult to keeping the parts separate during transport (via a secondary conveyor) to the product and waste belts.	FUTURE BUILDS. Future builds will have to have their product outfeed conveyor design customised to meet site requirements. A staggered outfeed conveyor would make sorting and transport of parts easier in some situations. A secondary conveyor could be integrated into any offering.
The small gap can be a snag point on certain product with very narrow ribs. This snag point can push the product out of alignment and result in a failed cut.	PARTIAL RESOLUTION. Operators are now trained to load the product beyond this snag point. This does not have a significant impact on throughput. PENDING UPGRADE. When at a suitable workshop, this gap will be modified to prevent any opportunity for the product to snag.
The LCBS was trialled with worn down pusher inserts to assess the impacts this has on production. It was determined that worn down pushers do increase the risk of failed cuts.	IN PROGRESS. An entirely new pusher chain and pusher insert configuration has been designed. When completed, this new product pusher system can be installed while the machine is on-site.
The cutting edge of one of the top (feather) circular knives chipped. After investigation it was found that this sort of damage has not been seen on other similar knives on similar systems and so is likely due to incorrect or incorrectly loaded product.	IN PROGRESS. The damaged blade will be replaced. If the damage reoccurs, further investigation will be required.

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