final report

Project code: P.PSH.0736

Prepared by: Steve Maunsell
Scott Technology Ltd

Date published: 9 May 2018

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 1961
NORTH SYDNEY NSW 2059

Lamb Boning Leap 2 (Hindquarter) Australian Site Ready Prototype

This is an MLA Donor Company funded project.

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

Abstract

Automating the Hindquarter boning process is seen as a useful portion of the fully automated lamb boning room.

Objective assessment of the performance of the previous Scott Hindquarter deboning development project identified that the key short coming was that the yield was less than the manual process.

The methodology of this project was to propose new technologies to address the yield demands and test the new technologies on a prototype development rig.

The yield results established on the development rig was worse than manual boning best practice and better than a manual boning poor practice, but reliability was traded off.

The project was unable to progress yield performance and reliability to a point that program refinement and overall process rate assessments could be made. The project objectives were judged as unlikely to be met and therefore the project was terminated.

Executive summary

Automating the Hindquarter boning process is seen as a useful portion of the fully automated lamb boning room.

An objective assessment of the performance of the previous Scott hindquarter deboning development project was made and the key short coming identified was that the yield was less than the manual process.

The methodology of this project was to propose new technologies to address the yield demands and validate the new technologies on a prototype development rig. A prototype development rig was built.

Part of the prototype development rig was the development of an improved product fixture and leg manipulation arms.

The Kuka force feedback technology package proposed as one of the new technologies for sensing was implemented and demonstrated to be of significant value for boning.

To enhance the sensing inference of Aitch bone feature positions by measuring alternative features was proposed and found to be unsuccessful, and seems unlikely to be a useful route. This is due to the absence of useful correlations within the Aitch bone.

The Aitch bone de-boning is a complex path, with multiple sections requiring complex strategies. The Aitch bone variation is significant making establishing the starting points and path adaption very difficult.

This project identified that the key to a viable Aitch boning machine was to achieve a reliable yield that is equal or improved compared with best practice manual boning. The yield results established on the development rig were worse than manual boning best practice and better than a poor processor, but reliability and process rate was traded off.
It is the view of the project team that a “break through” is required to change this tradeoff.

The project was unable to progress yield performance and reliability to a point that program refinement and overall process rate assessments could be made. The project objectives were judged as unlikely to be met and therefore the project was terminated.

Further benchmarking of the yield from manual boners across a number of processors should be done to assist with the yield goal setting and business case review.
It is our opinion that significantly improving yield beyond best practive will not be possible, but achieving consistently best practice with a mechanised approach will contribute to the justification. Other contributors are labour saving, training time, labour shortages and health and safety (over use injuries). For most processors not all hindquarters have the Aitch bone removed, which negatively impacts the business case.

The fundamental enabling technologies of sensing and cutting came up short in this project, which would be the areas for future development.

Sensing could be solved with a CT scanning approach, but currently limited by cost and process rate. But it is suggested that this route should be pursued anyway with the expectation that the cost and process rate is resolved with newer technologies.

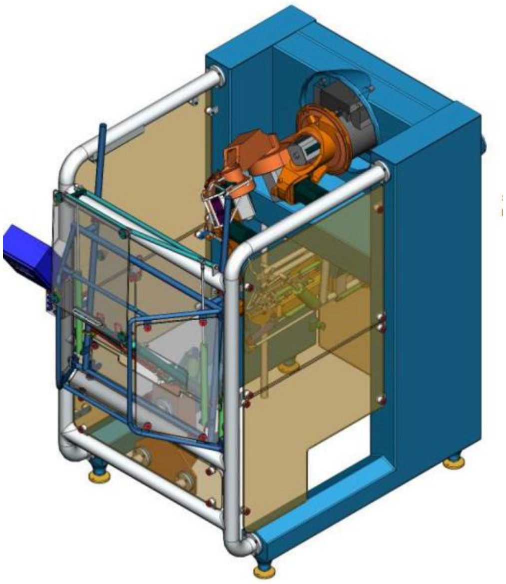
Conventional cutting is judged as adequate, but technologies that are more biased to readily removing meat (including tendons) and leaving bones behind (or visca versa) should be further explored.

Given advancement of the enabling technologies, and a defined business case, then an appropriate commercial Aitch boning machine could be readily developed. It would probably involve a multi fixture transfer device, such as a carousel and smaller faster washdown robots.

Table of contents

1 Background

2002 to 2006 Scotts developed a robot Aitch boning system to the point that a number were built and installed at the Silver Fern Farms, Silverstream site. Subsequently one of the machines was moved and incorporated into the Finegand automated lamb cuts room.
Significant production was run on the machines but reliability and yield performance shortcomings resulted in the machine being taken out of production.
Mayekawa[1] has had commercial offerings related to leg boning.



2 Project objectives

The participant will achieve the following objective(s) to MLA's reasonable satisfaction:

1. Revised and redeveloped an automated lamb hindquartering system that is fit for size range of Australian livestock
2. Revised and redeveloped an automated lamb hindquartering system that is smaller in footprint than the previously developed concept, with increased production rate and increased yield recovery.
3. Increased the current measured benefit (measured in New Zealand) of the system from $0.67 per carcass to a target of $0.85 per carcass.
4. Developed a system that can either operate standalone or integrate with a Scott x-ray system (the later would increase yield recovery and reduce cycle time)

At the completion of this project it is expected that an Australian processor (either Bordertown, Colac or Tamworth with no x-ray) will then be the host site for the installation of the above unit. It is at this point that a cost benefit analysis can be undertaken to ascertain both yield and speed improvement and the benefit based on processing Australian stock.

3 Methodology

3.1 Objective assessment of previous developments

A review was done of the performance, particularly yield, of the previous Scott development.

[1] (Mayekawa, n.d.), (Japan Patent No. US 7,198,564 B2, 2007)

3.2 New Technology path

The methodology of this project was to propose new technologies to address the yield demands and test the new technologies on a prototype development rig.

3.2.1 Train designers to Aitch bone

Designers were trained to perform manual Aitch boning by experts at Silver Ferns Finnegand site. The goal was for the designers be competent at boning and derive insight that could be engaged to initiate process innovations.

3.2.2 Create and select candidates for key aspects

Candidates for fixturing, sensing, cutting and pulling were created. Then an evaluation performed to select the most significant contributors to the required outcome. The key evaluation criteria is yield then process rate has been set as a lower criteria - given acceptable reliability can be achieved.

The fixture was developed with a combination of CAD, using a CT scanned Aitchbone generated model and workshop “knife and fork” development and trials.

It was proposed that measurements could be taken of key aspects of the Aitchbone and used to improve the predictions of the location of various Aitchbone features. Measurements were taken of a number of Aitchbones and statistical analysis done to establish correlations.

3.3 Build prototype development rig

A prototype development rig was built that enabled “in factory” validation of the proposed candidate solutions. The rig was to be suitable for operation in the process room. It was built with a minimum level of washdown capability.

3.4 Inhouse lamb leg boning trials and subsequent robot program development

The method employed was to develop Robot Software and force feedback infrastructure offline. Then employ the various techniques for sensing and cutting for each aspect of the boning path. Various trials were done on legs and Aitch bones at Scott’s premises.

A Benchmarking yield study was performed of the manual boners from a local processor and compared with the robotic outcome.

The intention, once yield results were encourageing, was to proceed to refining the process to enable an assessment of process rate and reliability.

3.5 Commercial solution considerations

The proposed method was to complete initial process rate developments and assessments to enable inputting to developing applicable concepts for a commercial solution.

4 Results

4.1 Previous development results

Objective assessment of the performance of the previous hindquarter deboning project by Scott's identified that the key short coming was that the delivered yield was less than being achieved by the manual boners. This is shown in Figure 1.

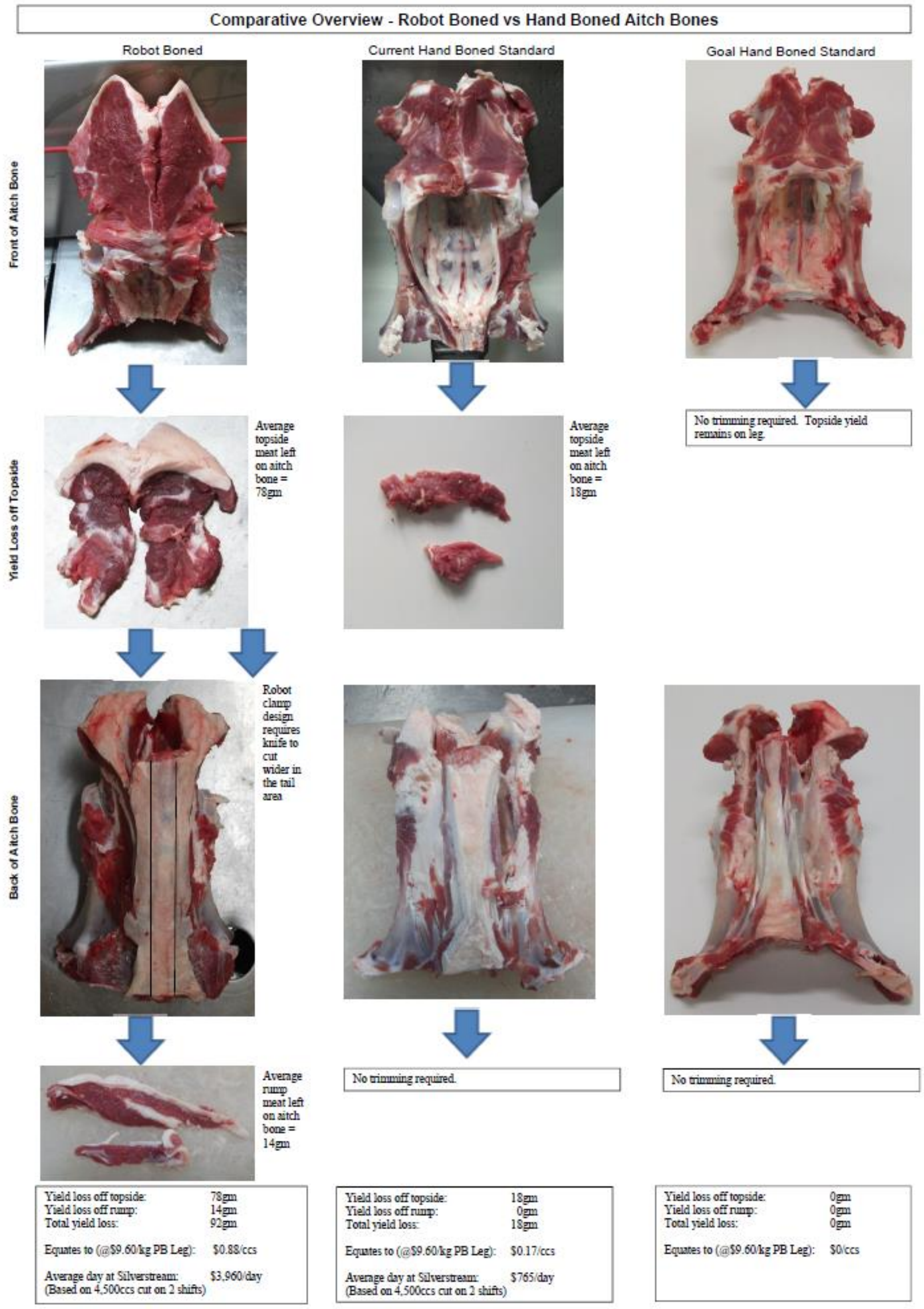


Figure 1 Background Robot versus Hand boned Aitch Bones

A summary report is included in paragraph **Error! Reference source not found. Error! Reference source not found.**.

4.2 New Technology path

4.2.1 Train designers to Aitch Bone

Two mechanical designers obtained knife tickets and were trained to "Aitch" bone. An adequate skill was obtained to understand the process, its key constraints and gain insight to enable development of the mechanised solution

4.2.2 Creation and selection of candidate solutions for key aspects

4.2.2.1 Fixturing

The scope for the fixture development was to firmly hold the Aitch bone while minimising obstruction of the robot. Ideally the Aitchbone would be held together, as it is known that the Aitch bone readily pulls apart. See Figure 2.

Figure 2 "Knife and Fork" development of Fixture

The fixture was progressed to a washdown production prototype. See Figure 3.

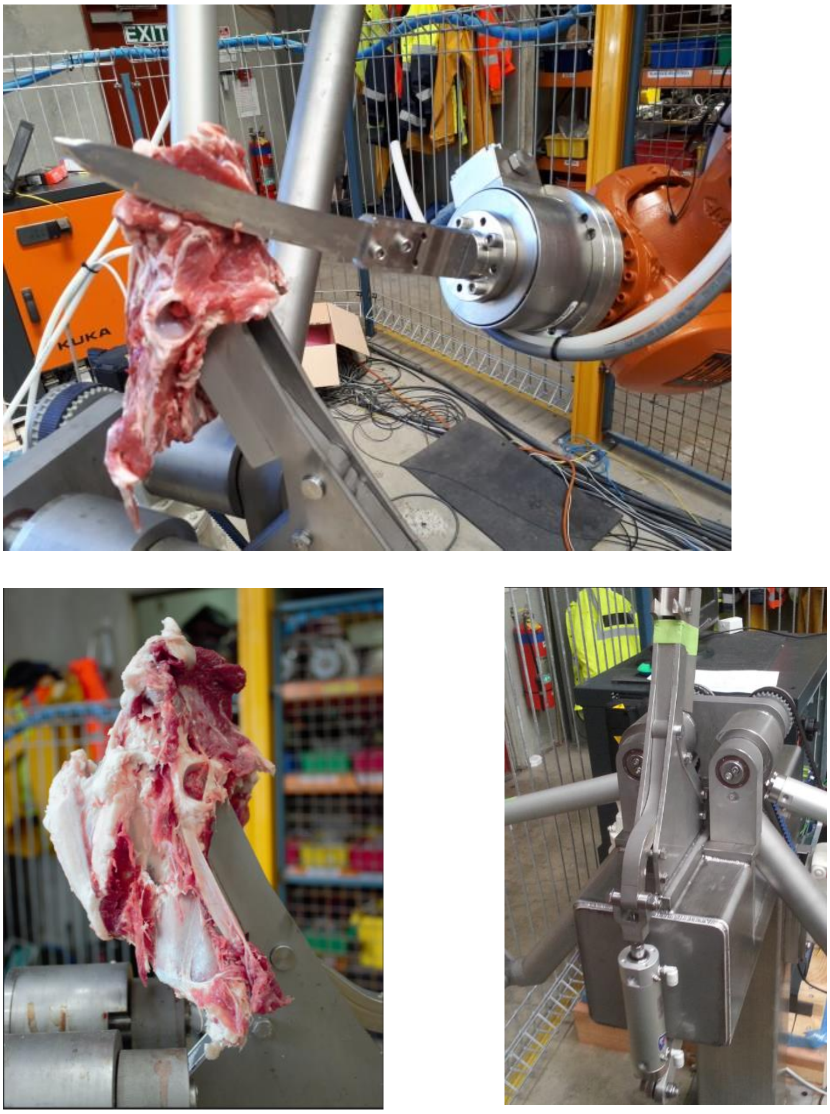


Figure 3 Production Prototype Fixture

The secure fixturing with minimal obstruction was achieved. There was no obstruction of the tail cuts. A partial solution was provided to hold the Aitch bone together. This still proved to be a limitation and the introduction of an additional clamp, sequenced into when the knife is clear, was proposed

4.2.2.2 Sensing

Kuka's force feed technology package was selected in combination with a 6 axis loadcell from ATI. Each axis of the Kuka robot can also be torque controlled. The force feedback technology package enables programming a force vector. It was demonstrated that driving the knife to a variably positioned surface was readily achievable. And it was demonstrated that selecting a suitable vector for scraping down a bone was also readily achieveable.
With this functionality, variably located surfaces can be readily measured. Therefore no additional measuring devices were included.

Figure 4 6 axis force transducer on the Robot

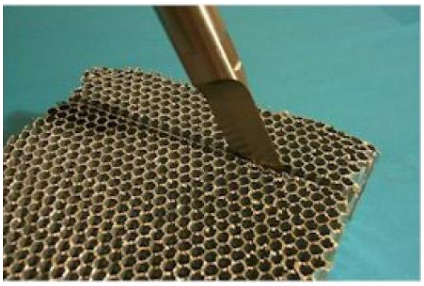
4.2.2.3 Cutting

The goal was to generate alternative means of cutting meat suitable for robotic boning. The key issue is for the cutting means to cut meat (soft material) but not "hang up" on the bone (hard material).

The generated list included:

- Ultrasonic[2]/Oscillating
- Rotating
- Knife shapes, bevels etc

Ultrasonic knife suppliers were consulted, meat cutting was known to them, and their advice was not encouraging. A tuned horn is required for each particular application which was judged as unlikely to suit the various cuts in the Aitch boning process.



Knife shapes, including knife grinding angle, exploration included:

[2] (Foster, 2006), (Dukane, n.d.), (Sonotronic, n.d.) ,(New Zealand Patent No. WO20121580049A1, 2011)

- Adding cutting detail to the back edge
- Using a version of the manual boning "flex" knife
- Grinding angle
- Cutting approach angle

4.3 Prototype development rig build

The scope of the rig was to enable validation of the Kuka force feedback system, cutting development and cut path program development.

The robot, including force feedback loadcell, fixture and leg pulling arms, form the prototype development jig. See Figure 5.

Figure 5 Prototype development rig

4.4 Inhouse lamb leg boning trials and subsequent robot program development

4.4.1 Benchmark testing

The benchmarking was done on a small sample before the project was terminated. Included in Table 1 are the results for the samples near the average, showing the actual Aitch bones and benchmark “scrapings” (recoverable yield). The results for the benchmark trial are tabulated in Table 2.

Process	Manual Deboning from Site P	Robotic Deboning	Goal for Hand Boned Standard
Aitch bone – Ventral view			
Scrapings (Recoverable yield)			

Table 1 Benchmark example result photographs

Sample Number	Manually Processed from Site P scrapings (recoverable yield)	Robotically Processed scrapings (recoverable yield)
1	110	0
2	220	10
3	150	10
4	100	20
5		45
6		55
7		55
8		70
Average	**145**	**33**

Table 2 Benchmark scrapings (recoverable yield) results

5 Discussion

The fixture development was to restrain the Aitch bone securely and minimise obstruction of the process, which was achieved with a significant improvement over the previous machine.

The leg pulling development was to manipulate the legs such as to gain access to key tendons and apply tension to facilitate boning. This was achieved with a significant improvement over the existing machine, demonstrating servo force or positional control. It was proposed that the arms could be moved towards the tail to further improve access for the robot.

The development work looking for establishing the location of various features, such as the pin bones, by inference from measuring measurable features, did not yield benefits in this project. Correlations of dimensions within the Aitch bone seem to be poor.

Kuka force feedback technology package was readily usable for finding surfaces and scraping down bones using the programmable force vector functionality. Additionally axis torque control was used. The use of the force feedback functionality was found not to contrain the cut path speed.

The development around new cutting technologies gave only minor gains, which included knife profiles, using the back edge and grinding angles. More radical options, such as ultrasonic cutting, was evaluated as not able to add value.

The initial separation cut which involved a path down the centre line and then force control around the ischium was successfully demonstrated. But then finding the start point on the Ischium front face, in two degrees of freedom, under the meat, is difficult. Failure modes included jamming down the wrong side (tail side) of the Ischium, approaching the ischium face at a non parallel angle, with a poor yield result and hitting the pin bone.
Finding the ball socket and cutting the tendons through underneath the ball was successfully demonstrated. The tail cut was work in progress, with mixed yield results and certainly process rate issues. The membrane cut under the ball joint on the Illium is critical for the meat pulling away cleanly. It often gave a good result but not adequately robust for production.

The benchmark testing showed that there is a huge variation from site to site and boner to boner. This does question whether merit associated with the potential consistency of a robotic solution has been understated. Clearly more benchmark results which include more sites would be beneficial.

6 Conclusions/recommendations

6.1.1 Conclusions

The product fixture and leg manipulation developments made significant advances.

The Kuka force feedback technology package was readily implemented, doesn't impact cut path speed and is of significant value for boning.

The inference of Aitch bone feature positioning by measuring alternative features was unsuccessful and seems unlikely to be a useful route.

The Aitch bone de-boning is a complex path, with multiple sections requiring specific strategies. The Aitch bone dimensional variation is significant, making establishing the starting points and creation of adaptive cutting paths very difficult.

This project identified that the key to a viable Aitch boning machine was to achieve a reliable yield that is equal or improved over best practice manual boning. Satisfactory yield was being achieved but tradedoff against reliability and speed. It is the view of the project team that a "break through" is required to change this tradeoff. Therefore this project was terminated.

6.1.2 Future path forward suggestions

Further benchmarking of the yield from manual boners across a number of processors should be done to assist with the yield goal setting and business case.

The business case should be further reviewed, it is our opinion that significantly improving yield beyond best practive will not be possible, but achieving consistently best practice with a mechanised approach would be possible and contribute to the justification. Other contributors are labour saving, training time, labour shortages and health and safety (over use). For most processors, not all hindquarters have the Aitch bone removed, which negatively impacts the business case.

The fundermental enabling technologies of sensing and cutting came up short in this project, which would be the areas to further develop.

Sensing could be solved with a CT scanning approach, but currently limited by cost and process rate. But it is suggested that this route should be pursued anyway with the expectation that the cost and process rate is resolved with newer technologies.

Conventional cutting is judged as adequate, but technologies that are more biased to readily removing meat (including tendons) and leaving bones behind (or visca versa) should be further explored.

Force feedback on the robot was applicable and it is suggested that a joint project with a Robot supplier could enhance the force feedback technology package performance for boning.

7 Key messages

7.1 Opportunity for lamb processing industry

A mechanised approach could potentially provide yield value from matching the yield from the best boners, but consistently for all production.

Value could be obtained from labour savings, removal of skill requirements, assist with labour shortages and heath and safety benefits from the reduction of over use injuries.

8 Bibliography

Dukane. (n.d.). *http://www.dukane.com/us/PFO Food.htm*.

Foster, A. (2006). *Alternative cutting techniques for the meat industry.* NORTH SYDNEY NSW 2059: Machinery Automation & Robotics Pty Ltd.

Hino, K. (2007). *Japan Patent No. US 7,198,564 B2.*

Mayekawa. (n.d.). *http://www.mayekawa.com/products/food_robotics/*.

Ross Douglas Clarke, S. R. (2011). *New Zealand Patent No. WO20121580049A1.*

Sonotronic. (n.d.). *http://www.sonotronic.de/technologies/ultrasonic/ultrasonic-cuttng*.

9 Appendix

9.1 Aitch Bone terminology used in this report