Final Report

AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

Beef striploin fat removal - Stage 2B:

Controlled variable thickness robotic fat trimming

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1.0 Executive Summary

A world first robotic solution for trimming striploin primal pieces has been in development by BMC (Koorosh Khodabandehloo) with support from AMPC and the Australian Beef sector.

Trimming to achieve a specific fat thickness on a beef striploin primal is a highly manual process requiring significant human skill and judgement. The sensory processes that allow determination of the fat thickness and the positioning of the striploin in the geometric space relative to a work datum are essential to automation developments.

With the use of ultrasonic measurements in a manner that determines beef striploin profile data in the robot frame of reference, the process of fat trimming automation has been realised.

Once the capability reaches commercialisation, the level of control to perform trimming to target fat cover specification will be beyond what is achievable manually. Human sensors could not have the possibility to gauge fat thickness within the striploin, except in a notional manner by feeling the top of the fat over the profile. Moreover, the control over the manual trimming process, removing fat is limited to the accuracies that may be achieved by the manipulation of a knife or a cutting tool being driven through the fat along the path that removes variable fat thickness to leave a known specific thickness behind on the lean meat.

Stage 2B has extended the work to date to develop and integrate a trimming tool with robotics and the sensory capabilities of previously executed AMPC projects. Test system has been trialled in a set up adjacent to a beef striploin processing line at a plant in Australia.

The project, in discussion with the plant hosting the trials, has improvised a Cobotic process as follows:

- After deboning, each striploin for the trial, has its top fat cover manually trimmed along the longitudinal edges, leaving an approximate 120mm-150 mm wide area a of the striploin untrimmed over the eye muscle. The prepared striploin, with top fat cover untrimmed is presented to the robot for profile measurement and trimming.
- The robot performs measurements of the profile using laser and ultrasonic sensing and the robot program, specially coded in the project determines the slicing paths for fat removal. This program calculated the position of the blade along the slicing path and the depth gauge distance above the blade for each node measured.
- The robot carrying the tool removes non uniform layers of fat controlling the gauge position above the blade and the position of the rotating blade, moving the cutter along two adjacent paths separating fat from the striploin, leaving the specified thickness of fat behind.

The controlled process reduces the over trimming often observed in the manual process. This system has been demonstrated to AMPC and staff at the host trial plant. The results demonstrate capability as follows:

- The controllable tool for robotic trimmer performs better than 2 mm reduction in over trimming.
- For all the 51 primals trimmed by the robot:
    - no damage was caused by the blade into striploin,
    - persons in charge of the production examined each primal,
    - all primals trimmed along the two passes, over the main eye-muscle conformed to specification without over trimming. Plant management observed that robot trimmed primals had a higher fat cover compared to the manual process,
    - trimmed primals were packed and dispatched as normal.

Stage 3 proposes to reach a Cobotic prototype solution as a world first production for trials late 2024.

2.0 Introduction

Trimming striploin primal pieces by manual manipulation of a knife, slicing through fat to leave a uniform layer, requires judgement and dexterity. This is a complex task for workers on a beef trimming line and the result of over trimming yield losses. The main reason is that there is no sensing or guidance for a person to know where the fat-lean interface is within the body of the striploin primal.

Stage 2B extended the developments to date by developing a controllable fat trimming tool, modifying, and extending the construction of a hand trimmer, making automatic the manually adjustable depth gauge restrainer over a powered rotary the blade to dynamically change the thickness setting with a motorised drive solution. Integration of the sensing (based on ultrasonic method validated under stage 2A) and a new trimming tool, in the robotic set up, provided the capability to validating a controllable fat trimming process against customer specified fat thickness to remain on beef striploins.

The integrated solution has achieved the capability to perform fat separation trials in an experimental set up with the trimming tool mounted and operating under robot control. The program takes measurement of fat profile and meat thickness using laser sensing and an ultrasonic probe for trials with striploin primal pieces.

Prior trials tests have observed the manual process of trimming against specified fat cover thickness and corresponding Quality Assurance (QA) process checking for conformity. Over trimming is common in the manual process and spot checks reveal that the average loss per primal pieces in the manual practice can be over A$3.00 per striploin. The robotic process, providing the control to automatically adjust the depth of separation for uniform fat cover, avoids such losses.

The integrated test system, as an engineered R&D solution has been trialed at a plant in Australia. The trials included over 50 primal pieces under, trimming the ‘top fat’ over the main striploin muscle, documenting capability. The tests were performed adjacent to the production line.

The trial procedure included:

- Set up and testing prior to trials start, presenting to Plant Management the robot process.
- Agreement with Plant the location and the trial process avoiding damage or loss of yield.
- Planning of execution timing with the plant (including testing during night shift).
- Hygiene and QA procedures to be followed.
- Agreement on process for trimming primal pieces taken from the line and returned to the line.
- Communication and people to connect with during the period of the trial including night shift staff.

Manual pre-trimming of the striploins provided the required top-fat cover for robot trials, with the robot making two longitudinal passes over the main section of the eye-muscle, where over trimming would have the worst impact on the finished ready to pack striploin primals.

Feedback from the Plant was recorded as trials proceeded for each primal piece trimmed by the robot and the striploins checked for conformity and returned to the line for packing.

The controllable robot trimmer has been demonstrated to host processing plant staff and AMPC with the potential for a next stage development considered within reach as a world first production demonstrator.

3.0 Project Objectives

- Implement a controllable fat trimming tool for use with a robot.
- Integrate the tool with existing robot cell and develop robot cut path algorithms using sensory data from Stage 2A.
- Assess the system in compassion trials with manual trimming to demonstrate capability and show improvements that avoid over trimming by at least 2 mm. Test runs to be based on 10 striploins per run for 5 runs over 5 days.
- Report on findings and update value proposition for a production solution.

4.0 Methodology

- Use sensory data (Ultrasonic and Laser sensing) to define separation paths for a robot to drive the trimmer blade along.
- Use FH (Fat Height) and MH (Meat Height) to determine change in restrainer position to vary the gap between the blade and the restraining depth gauge as along each path over the striploin eye-muscle above the meat to leave a uniform layer behind (Figure 1 - right).
- Add servo drive to control the restrainer position.
- Adapt tool mounting for use with robot.
- Implement control instrumentation to drive the restrainer positioning mechanism to allow control of fat position to hold and adjust to the desired thickness during motion of the cutter by the robot.
- Integrate and test.
- Run trials for improvement of set up.
- Install adjacent to the line to allow test runs with QA conformity checks comparing with manual process.

The combination of the laser profile measurement and ultrasonic meat thickness at nodes of interest over the volume of the striploin are to provide the paths of separation in a manner that leave a specific fat thickness on the meat, avoiding over-trimming. Fat separation along specific trimming paths is achieved by the moving and blade adjusting cutter blade position and restrainer traversing the tool along the striploin.

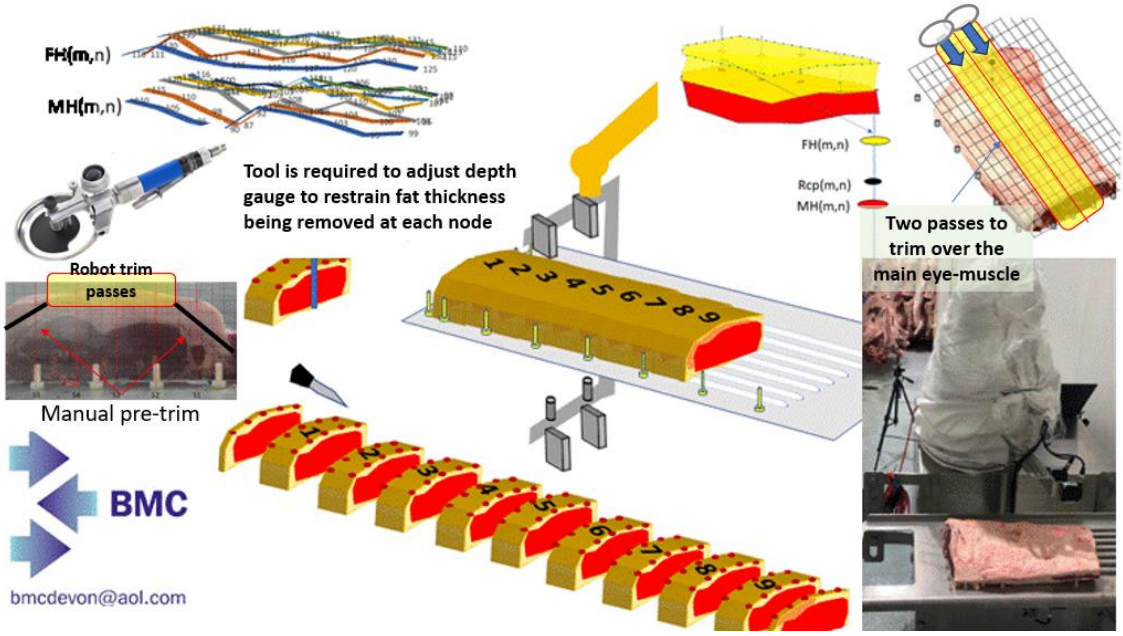


Figure 1: Controllable trimmer for leaving a uniform fat cover on the striploin.

5.0 Project Outcomes

Trials have been conducted using the robotically controllable and adjustable depth gauge trimming 'wizard' tool. This has shown the controlled capability of the developed tool under Stage 2B for striploin uniform fat cover.

Table 1 presents the results for the 51 striploins.

		mm after trim			Correction
		Measured			OR
No	Spec.	M1	M2	M3	Damage
1	**10**	10	12	10	None
2	**10**	10	10	11	None
3	**10**	10	12	10	None
4	**10**	10	10	9	None
5	**10**	13	10	12	None
6	**10**	11	12	10	None
7	**10**	10	12	10	None
8	**10**	10	10	10	None
9	**10**	9	10	10	None
10	**10**	10	10	10	None
11	**10**	10	10	10	None
12	**10**	10	10	10	None
13	**10**	10	10	10	None
14	-	15	15	13	None
15	**10**	10	10	10	None
16	**10**	10	10	10	None
17	**10**	10	12	11	None
18	**10**	10	11	10	None
19	**10**	10	10	14	None
20	**10**	10	10	12	None
21	**10**	12	12	12	None
22	**10**	10	10	10	None
23	**10**	(15)	(15)	(10)	None
24	**10**	10	10	10	None
25	**10**	10	10	10	None
26	**10**	(10)	(10)	(10)	None

		mm after trim			Correction
		Measured			OR
No	Spec.	M1	M2	M3	Damage
27	**12**	12	12	12	None
28	**12**	10	12	12	None
29	**12**	12	12	12	None
30	**12**	10	12	10	None
31	**12**	12	12	12	None
32	**12**	12	12	12	None
33	**12**	12	12	12	None
34	**12**	12	12	12	None
35	**12**	10	10	12	None
36	**12**	12	12	12	None
37	**12**	12	13	12	None
38	**12**	10	10	10	None
39	**10**	10	10	11	None
40	**10**	8	8	9	None
41	**10**	10	14	10	None
42	**10**	10	10	10	None
43	**10**	10	10	10	None
44	**10**	10	10	10	None
45	**10**	10	8	10	None
46	**10**	10	10	10	None
47	**10**	10	10	10	None
48	**10**	10	10	10	None
49	**10**	10	10	10	None
50	**10**	10	10	10	None
51	**10**	10	10	10	None

Table 1: Trimming of Striploin Primal by robot using a controllable powered trimmer.

The measurements of fat M1, M2 M3 at three points correspond to QA practice. See Appendix select images striploin primals corresponding to the item numbers in Table 1. Figure 2 shows and Appendix present a selection of images from the trials and fat cover measured. A full set and videos may be provided on request.

Figure 2: Robotic beef striploin trimming for uniform fat cover.

6.0 Conclusions / Recommendations

A controllable powered tool for use robotic trimming has been defined, assembled, and integrated, for testing in planned trials under Stage 2B. The results show capability in fat trimming of striploins avoiding over trimming by at least 2 mm.

The results of the Trial have been considered positive by the team at host Plant. This has been based on the firsthand viewing of robot trimming results over the period of the trial as executed to conclusion under this AMPC R&D project. The system has been demonstrated to plant management and AMPC representatives.

Stage 3 as a follow up project is anticipated to integrate a robotic line, where the trimming approach defined under Stage 2B may be adopted to reach a production protype, with striploin preparation and pre-trimming by hand before, with the integrated robot trimming passes giving the best fat cover to specification, with much reduced over trimming. Calculations reveal that savings of more than $3.00 per striploin may be expected, with 50% efficiency gain, with the robot performing two trimming passes on each striploin, at 120 striploins per hour.

Stage 3 proposes to reach a Cobotic prototype solution as a world first production for trials late 2024.

For further information contact AMPC or bmcdevon@aol.com (K Khodabandehloo).

7.0 Acknowledgements

Special thanks are due to AMPC for funding this project and the input and support for JBS Beef City.

The efforts of Fraser Border (RAMS Australia), working with BMC on this project is very much appreciated and duly acknowledged.

8.0 Appendix

Example of trimmed primals by robot with left and right edges of the striploin trimmed manually prior to robot runs.


02 (8) IMG_4794


02 (8) IMG_4801


02 (8) IMG_4804


02 (8) IMG_4805


02 (8) IMG_4808


04 (10) IMG_4826


04 (10) IMG_4837


04 (10) IMG_4840

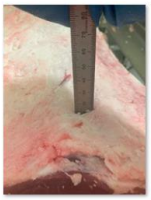

04 (10) IMG_4841


04 (10) IMG_4842


07 (13) IMG_4884


07 (13) IMG_4890


07 (13) IMG_4891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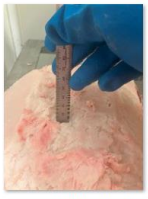
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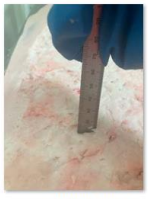
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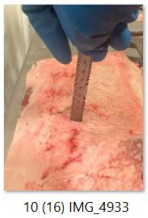
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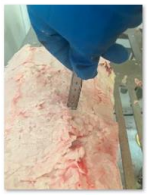
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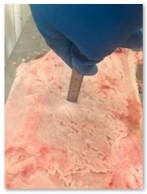
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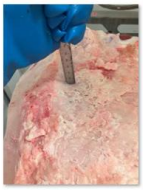
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25 (31) IMG_5124


25 (31) IMG_5125


26 (32) IMG_5133 no US - 2mm


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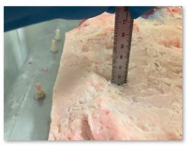
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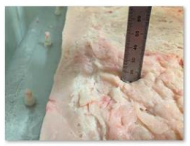
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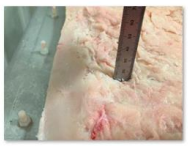
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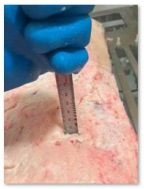
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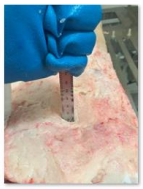
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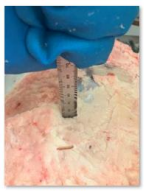
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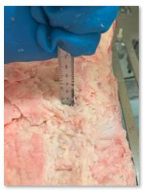
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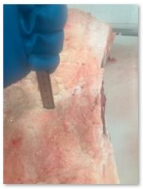
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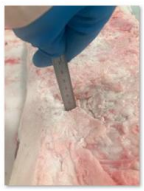
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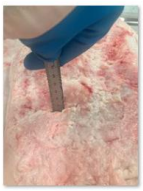
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