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LEAP4Beef – DEXA cut information translation using carcase marking and verify proposed cutting and processing methods are suitable for TEYS production

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Abstract

This project was to generate and verify cutting technologies, cut paths and a cut sequence that will deliver suitable product for use in the TEYS automatic beef boning room project P.PIP.0722. The project contributes to the MLA beef boning automation strategy.

Alternative cutting strategies were evaluated on compliance with Ausmeat specifications, enhancement of the value of resultant cut portions, product specification flexibility and suitability for automation.

SCOTT staff liaised with TEYS product and process specialists and established the required cuts to produce the final products. The various proposed cuts were trialed, with TEYS staff at Rockhampton and suitability assessed. Six alternative solution paths were trailed.

The automatic bone-in cutting strategy that is agreed to be the best way forward will have manual preparation followed by two separation systems.
System 1: Would include a sensing device, such as an X-Ray room and 2D colour cameras. The defined cuts are to separate the brisket, short ribs and the leg.
System 2: Would include a CT scanner. The defined cuts are to separate the chuck/rack and the rack/short loin. And include chining of the rack and the short loin.

A precursor to this system is the development of grading system without the cut through the spine and a meat processor suitable CT scanner.

Executive summary

Aims of the research

This project was to propose and validate cutting technologies, cut paths and cut sequences suitable for the TEYS automated boning room project P.PIP.0722. The TEYS automated boning room project is part of the MLA Beef Boning Automation strategy program. The TEYS automated boning room project includes sensing and cutting means to perform a number of primal bone cuts and incorporates the SCOTT/MLA beef middle machine. It has been reported that the automated beef boning room has potential to add $30 per carcass.

Method

Criteria was established to evaluate the alternative cutting strategies. The evaluation criteria included compliance with Ausmeat specifications, enhanced value of resultant cut portions, product specification flexibility and suitability for automation. Suitability for automation includes being able to mechanise the cuts, clamping and coping with resultant distortion from sensing equipment to cutting stations.

SCOTT staff liaised with TEYS product and process specialists and established the required cuts to produce the final products. Critical issues were identified that mechanisation would have to take into account to avoid loss of value or yield. Then six alternative solution paths were trailed, utilising the TEYS experts and evaluated utilising the evaluation criteria.

Results

The automatic bone-in cutting system that was evaluated and agreed as the best way forward has manual pre-work processes followed by two separation systems. The supplied sides will not have the grading cut.

1. Manual pre-work process
    a. Remove the fore leg complete with blade meat
    b. Remove the flank
    c. Remove or partially remove items including the tenderloin and inside skirt so that they are clear of the separation cut lines
2. First separation system
    a. Removal of whole brisket
    b. Removal of whole rib set (short rib strip)
    c. Seperation of chuck/rack/short loin from Hind leg
3. Second separation system – with CT sensing means
    a. Chuck/Rack and Rack/Short loin spine cross cuts
    b. Chine the rack
    c. Chine the loin

Benefits to industry

This project has established cut paths and a process that could enable automation of the beef primal separation process and chining of racks and loins. The opportunity is to increase product value by utilising improved accuracy to increase value of the adjoining portions where value differs and

reduce out of specification cut products. And geometry or intramuscular fat from CT data could be used to drive an integrated steak grading and cutting system.

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1 Background

1.1 Reasons for research

This project was contracted to add knowedge to the MLA Beef Boning Automation strategy program. Where the MLA Leap 4 Beef program has developed scribing at JBS Dinmore (Trieu, et al., 2016), various refinements of sensing technologies (Nicholson, et al., 2019) and proposed alternative overall cut sequence and handling concepts (Seaton, 2017), (Maunsell, et al., 2018).

The beef boning processors in Australia are significantly split into either side or the quarter boning process. And there is a grading cut, of processor defined length and specified rib location.

The previous projects have identified contraining automation solutions within these constraints has limited automation solutions development.

TEYS, partnered with MLA, have embarked on a prototype beef automation system.

The TEYS boning room project includes sensing and cutting means to perform a number of primal bone cuts and incorporates the SCOTT/MLA beef middle machine.

SCOTT has experience with the automation of lamb primal separation and downstream machines, such as hindquarter, middle and forequarter machines. This journey has highlighted the importance of establishing the key requirements to maintain product value and identify opportunities to increase value to the processor. Cuts performed by mechanical means have been shown to be contrained such that there are differences from the current manual processes. Experience has identified that these differences need to be explored and consequences quantified.

1.2 Significance for industry

This project was to create and validate that the cuts and process sequences are suitable for the TEYS Automated Boning Room Project P.PIP.0722. The benefits to the processor from greater cut accuracy and labour savings have been put at over $30 per head.

Should the proposed cuts and sequence not be contrained by the existing side or quarter boning process, including the grading cut, the automation implementation may necessitate significant chance to existing processing facilities. Additionally a replacement

1.3 Key Aims

The key requirement is that the proposed cuts increase value when cut with greater accuracy. Increased value can be obtained from the following:

- Reduce waste by reducing the width of the cut
- Increase value of adjacent portions due to cut placement
- Increase percentage of resultant portions that are within specification

2 Project objectives

The project objective was to:

- Manually replicate the proposed automated cutting technologies and methodologies to verify that the product outputs are capable of integrating back into TEYS production and are suitable for meeting TEYS customer requirements and specifications.
- Achieve agreement from TEYS, MLA and SCOTT that the proposed process and methodology is suitable to base an automation solution around.

3 Methodology

3.1 Overall method

The requirement was to liaise with TEYS and explore the alternative cut positions and locations in the process.

In this project the overall suitability for automation are included in the evaluation.

Alternative process solutions were proposed and trialled, as listed in **Error! Reference source not found.**. The proposed candidates explore ensuring no loss of yield or downgrading, flexibility in delivering the required product specifications and suitability for automation. The trial evaluates product distortion through the process as it relates to downstream automated processes.

SCOTT staff met with TEYS personnel in Brisbane on 3rd October 2018 to generate the alternative cutting strategies and establish the value opportunities and constraints.

Sides with no grading cuts were used to undertake the planned tests at TEYS Rockhampton beef processing plant on the 13th and 14th August 2019. Each test was completed before the next test was started.

The work was performed by highly skilled members of TEYS on site processing team.

Cut lines in accordance with specified targets points and angles as defined during the meeting of 3rd October 2018 were identified and marked using a straight edge, a square and stainless steel pins.

Preparatory work was performed in accordance with the test plan.

Sides were cut using an air saw for the rib cuts, a hand saw for the spine cuts and a hand knife for soft tissue cuts.

Where pieces were separated from the side of beef, cuts were made to the side as it hung from a rail trolley (also known as a roller or hook). Where more than one conventional primal piece was removed from the side joined together, they were separated on a stainless steel table using a hand saw and knife.

After primal cutting, a set square was used to assess the squareness of cuts.

A limited amount of chine cutting was performed using a conventional band saw.

After each process step, sides were photographed from the same tripod location. A plumb bob with steel balls at 100mm centres was included in all photographs to facilitate some degree of image scaling.

3.2 Justification of methods chosen

It is purported that the methods chosen are appropriate because the key experts in the key areas were included. Beef processing, regulatory constraints and value analysis was provided by TEYS and automation expertise provided by SCOTT. TEYS has also engaged Greenleaf to assist with benefit analysis going forward. SCOTT has experience in mechanising the lamb primal cuts.

3.3 Solution Selection criteria

The selection criteria was

1. Compliance with AUS-MEAT[1] specifications as the regulatory authority
2. Establish cut positions and cut means such as to maximise the value of resultant meat portions.
3. Establish cut positions and cut means, such as to minimise loss, or downgrading, of product.
4. Achieving maximum number of product specifications and flexibility
5. Process suitability for automation

    a. Condition of supplied product and preparatory processes
    b. Ability to sense anatomical features which define the cut lines
    c. Real estate on the product such that it can be held while cuts are performed
    d. Cut can be performed with a mechanised means
    e. Solution for carcass distortion between cut position sensing and cutting (including during the cut)
    f. Means to reliably deliver the product for subsequent processing with damage.
    g. Variation in product size and shape can be accommodated with clamps, sensor positions and cutter orientations.

The solution selection evaluation is approximately weighted in the selection criteria order, 1 to 4, as above.

Discussions with TEYS dictated that the AUS-MEAT specifications must be complied with. Where AUS-MEAT cut definitions conflict with achieving optimum value, to get optimum value the conflict will need to be resolved with further work outside of this project.

The consequence of the selection criteria is that all solutions will comply with AUS-MEAT specifications and, for some proposed solutions, suitability for automation and sensing means is yet to be validated. Therefore development and validation of technologies for automation and sensing is being developed in other projects, such as:

- P.PSH.1200 LEAP4Beef DEXA and 3D Sensing evaluation for markers guiding TEYS Primal cut paths[2].

[1] (AUS-MEAT, 2005)
[2] (Kennedy, 2019)

- P.PSH.1204 LEAP 4 Beef Cut information translation using carcass marking for TEYS automated beef deboning[3]
- P.PSH.0893 LEAP 4 Beef Sub project 1 – Automated Chine, Button and fat trim proof of concept for the striploin and cube roll[4].

3.4 Method evaluation and relevance

The process cuts are significantly entrenched in each processor, from sales specifications through to plant floor, therefore changing the intermediate portions to suit automation is a significant challenge. Hence the liaison and establishment of solution selection criteria. Optimising the automation process with TEYS alone has significantly assisted this process. It is suggested that progressing automation solutions, for the optimised solution established for TEYS, will still largely be relevant for the wider Australian beef processing industry.

Alternative approaches, such as being constrained to the current manual process, constrained to current known automation solutions or development in isolation from the processor were discounted.

The approach taken, liaison with TEYS, establishing the cut positions to suit AUS-MEAT, quantification of increase in product value and suitability for automation, is aligned with verification that the cutting technologies proposed and the cut paths/cut methods proposed are suitable in delivering a product suitable for use in the TEYS Boning room project P.PIP.0722.

The proposed solutions were evaluated with the established solution criteria in a qualitative way.

Given a relatively small number of solutions to evaluate and the project being early conceptual work, qualitative analysis is appropriate. The recommended solution is sufficiently accurately chosen to suit the subsequent development projects.

4 Results

4.1 Results

4.1.1 Process Integration

To fit with recent and evolving development work, an automatic bone-in cutting system would fit after a vision room and feed bone-in middle pieces to a CT scanning and processing line.

[3] (Liddell, 2019)
[4] (Kennedy, et al., 2019)

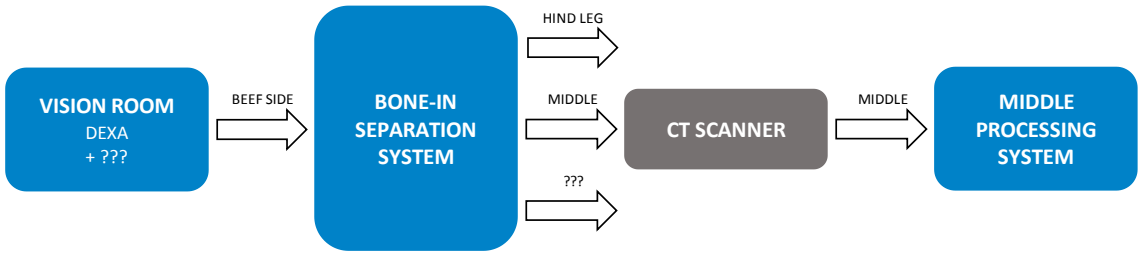

Fig. 1

4.1.2 Cut positions and mechanised cut solutions to maximising the value of resultant meat portions.

The cut positions are constrained to the Ausmeat specifications – gaining value by adjusting the cut position to increase value of the resultant meat portions is limited to achieving greater accuracy with the automation than the manual process and utilising the acceptable tolerance band.

The proposed cut means include:

Cut	Cut Means
A	Bandsaw or saw
B	Bandsaw or saw
C	Bandsaw or saw plus knife through eye muscle
D	Bandsaw or saw plus knife through eye muscle
E	Bandsaw or saw plus knife through eye muscle

Cutting means preference is knife through meat and bandsaw through bone. A strategy chosen to minimise yield loss. Where a bone cut has a “deadend” or is part depth, then a rotary saw is the remaining option.

4.1.3 Condition of supplied product and preparatory processes – Grading Cut

Trials 3 and 4 demonstrated clearly that a cut through the spine severely compromises stiffness of the side. The result is that automated handling, sensing, and cutting with the grading cut, would not viable.

4.1.4 Condition of supplied product and preparatory processes – Preparatory Work

Separation of the flank from the leg is best done manually because:

- Automation won’t improve accuracy (hence value)
- Automation will be difficult and expensive requiring (among other things) CT scanning before the cut is made

Complete removal of the flank before bone-in separations is necessary to:

- Prevent damage from over-travel of the brisket and short-rib strip cuts
- Prevent obscuration of the caudal end of the brisket cut
- Allow the brisket and short-rib strip to be removed with one straight cut

Removal of the foreleg complete with blade meat is necessary to facilitate automatic separation of the whole brisket (including brisket point) and to facilitate automatic separation of the chuck short ribs as part of the whole short rib strip without damaging leg and blade meat. Removal of the leg in pieces from a hanging side is consistent with current side boning practice in Australia. Removal of the leg as a whole banjo fore is a possibility that has yield benefits and could be achieved with development of a manual assist or automatic device in the future.

Where the tenderloin and / or the inside skirt are to be manually removed as whole pieces, they must be removed or partially removed to prevent damage during automatic bone-in cutting.

4.1.5 Means to sensing anatomical features which define the cut lines

Sensing of the anatomical features to define the cut lines is the topic of research in project P.PSH.1200 LEAP4Beef DEXA and 3D Sensing evaluation for markers guiding TEYS Primal cut paths. The available technologies include:

- Colour camera, including 3-dimensional stereo imaging
- 3D ruler scanning
- X-Ray (including DEXA)
- Where all these technologies can be local, dynamically relocated and used in combination.
- Various analysis techniques will be evaluated

4.1.6 Real estate on the product such that it can be held while cuts are performed

The proposed cuts for automation, and the required real estate on the product to enable clamping for handling and clamping have been considered. In principle there is real estate to hold the product that is clear of the brisket and short ribs cuts. The strategy of holding and cutting will need to be a topic of research in a future project.

4.1.7 Solution for carcass distortion between cut position sensing and cutting (including during the cut)

Distortion from whole side to after flank removal has been identified in solution 2 (and equivalent solution 6).
Distortion in solutions with the grading cut is significant and automation is not viable.
The distortion (including twist) after the brisket and short rib cuts exceeds the accuracy requirements and will need addressing. This issue is typically referred to as re referencing and is a topic of research outside this project.

4.1.8 Means to reliably deliver the product for subsequent processing.

It is suggested that delivering cut product portions reliably to subsequent processes will be achievable. Product could be free to drop or supported with a robot and placed.

4.1.9 Variation in product size and shape can be accommodated with clamps, sensor positions and cutter orientations.

The generated strategy for automation identifies clamping requirements for each cut. Clamping requires defined regions on the product clear of subsequent cutting devices. The size range of the products will mean that the clamping for cross cutting and chining will need to be adaptively placed

in predetermined approximate locations to clear the clamps. These challenges are a topic of research in project P.PSH.0893 LEAP 4 Beef Sub project 1 – Automated Chine, Button and fat trim proof of concept for the striploin and cube roll.

4.2 Evaluation of results

All solutions are constrained to product products compliant with Ausmeat specifications.

Potentially there is the possibility of chining the rack / loin as one piece allowing separation independent of bone structure without affecting back ribs or the chine bone. The benefit would need establishing before adding this complexity into the middle machine.

5 Discussion

5.1 Summary of results and relevance

The proposed process prioritises enabling the rack/chuck and rack/loin separation cross cuts to be performed as accurately as possible – using CT data in the beef middle machine.

Utilising the middle machine also enables the possibility of integrating steak cutting with CT driven dimensions and individual grading.

There is also the possibility of adding value from CT data driving the cross cut positions from muscle parameters and generating subsequent product selections.

However, given the requirement to comply with the Ausmeat specifications the immediate goal is that the automation solutions can cut more accurately than the currently accepted tolerance bands and therefore the cut positons can be tune to use the tolerance band such that it favours the processor.

The brisket and short rib portions in the proposal are removed in single pieces, which enables further manual cutting into the various brisket and rib set products.

There has been considerable liaison with TEYS regarding the location of the brisket cut and associated short rib cut. The Ausmeat definition, on smaller carcasses, can be in conflict with fitting 170mm rib set in the chuck and two sets in the rack. Subsequent projects should measure anatomical features to establish both the Ausmeat definition and the 170mm (or 340mm) linear dimensions from the edge of the spine to enable either specification, or a combination, to be used.

The proposed cuts create intermediate portions suitable for TEYS production. The sequence of cuts has been evaluated regarding being the most likely solution for the TEYS automation project, P.PIP.0722.

5.2 Issues identified

By necessity the judgements made in this project are on very small samples. The results from small samples are seen as appropriate for concept formulation but variation inherent with meat processing needs to be reconsidered throughout subsequent developments. There is a risk that

downstream issues related to product variation could be encountered and necessitate concept changes.

A key issue with automation is that the range of cuts needs to be established in the scope at the initiation of the design phase. Hence this project. However this is demanding on any processor as they are accustomed to readily making changes in their current manual process. Alternative products anticipated in the scope can be accommodated but new requirements won't be possible.

Automation is typically best grouped and kept separated from manual operations because of guarding or shielding, in the case of X-Ray, requirements. And the manual operations are best grouped for social and management reasons. Ideally the anatomical markers could be sensed in the clamp for cutting without the constraints of an X-Ray room. And the preparatory work performed prior to the sensing and cutting. This would leave the meat/fat/bone grading process independent of the cutting automation. However should the X-Ray room need to be used ideally the scapula would be removed, to allow improved X-Ray transmission and associated improved imaging – but this would be in conflict with grading an entire carcass. The alternative options for sensing of the anatomical markers is key research topic in project P.PSH.1200.

5.3 Future Directions

The future direction is to continue liaison with TEYS and monitor agreement that the proposed cuts in this project are accepted.

Project P.PSH.1200 LEAP4 Beef DEXA and 3D Sensing evaluation for markers guiding TEYS Primal cut paths is underway. Discovery and validation of appropriate sensing technologies to establish the anatomical features to define the brisket and leg cuts that suit the automation project is key to defining the final process.

Project P.PSH.0893 LEAP 4 Beef Sub project 1 – Automated Chine, Button and fat trim proof of concept for the striploin and cube roll contract is very close to being executed. The project has been varied to suit the input product being the one piece chuck / rack / short loin. The project includes the concept creation and knife and fork demonstration of adaptive size driven clamping, off line CT scanning, anticipation of rack / chuck and rack / loin cross cuts and automated chining. Automated fat removal and button bone conceptual work and knife and fork demonstrations have been completed. The incorporation of the developed automated fat removal is not suitable and not being pursued in project P.PSH.0893 or in the proposal for TEYS automation project.

Project P.PSH.1204 LEAP 4 Beef Cut information translation using carcass marking for TEYS automated beef deboning is underway. P.PSH.1204 is establishing alternative means of physically marking beef such that it enables sensing and marking the cut lines remotely, then reading the marks and re-establishing the geometry positions for cutting.

The increase in product value, reduced downgrading and yield loss will all need quantifying in future work.

Commercial justification determination will only be possible after the product value enhancement exercise and the automation equipment has been determined I subsequent projects.

6 Conclusions/recommendations

6.1 Key insights and implications

The biggest value add opportunity is get the spine cross cuts placed more accurately to the Ausmeat specification than performed manually.

The value proposition could be further enhanced by adjusting the spine cross cuts based on quality or geometric parameters from the enhanced sensing. This could be further enhanced with the integration of steak cutting.

Achieving 170mm rib sets is critical to maintain product value. This requirement can be in conflict with the chuck end of the Austmeat brisket cut specification.

The brisket can be cut into various products which complicates automation and therefore a single piece brisket strategy was chosen for the automation and the subsequent products are to be created manually.

Manual processes are ideally grouped separate from the automation processes for social and safety reasons.

The chosen cut strategy defines the prework cuts that are unsuitable for automation and breaks down the carcass such that it will fit through a CT scanner to enable driving the most valuable cuts off the high quality 3D data.

6.2 Future R&D

It is recommended that multiple products are processed to this cut strategy, in a contrained mechanised way as per the automation solution. As the determination in this project is based on very small product samples sizes. Variation encountered from the whole population could alter the determination.

The value proposition should be validated by a beef yield specialist.

Key enabling “inventions” to advance the TEYS automatic beef boning room include:

- Sensing of parameters to feed into MSA grading as obtained from grading cut – without the grading cut
- Sensing the defined cut markers by either 2D colour camera’s, 3D cameras or X-Ray
- Clamping or re-referencing to maintain sensed data
- Clamping to enable the primal cuts
- Cutting technologies to enable the primal cuts
- Suitable CT scanning means – including clamping or re-referencing
- Clamping to enable the middle spine cross cuts and chine removal
- Algorithims to establish optimum value add for integrated steak cutting

A number of these enabling “inventions” are being sought in project P.PSH.1200 LEAP4 Beef DEXA and 3D Sensing evaluation for markers guiding TEYS Primal cut and Project P.PSH.0893 LEAP 4 Beef Sub project 1 – Automated Chine, Button and fat trim proof of concept for the striploin and cube roll.

6.3 Practical application of project outcomes

The most immediate practical application of the cutting strategy from this project is to implement in the TEYS automated beef boning room.

The cutting strategy generated in this project is tailored to automation, there is unlikely to be benefit for manual boning processors.

The goal is that the proposed cutting strategy will be implemented in future automation projects with additional Austrailan processors.

7 Key messages

This project proposes that performing a significant change to the Beef processing process enables obtaining significant value opportunities with automation.

A precursor is finding a solution for grading without the grading cut and performing the chuck/rack and rack/loin cross cuts off data from incorporating the CT scanning of chuck/rack/short loin as an intermediate portion. Which requires a boning room suitable CT scanner.

Automation in the beef space requires significant understanding of the value opportunities to enable the support of the significant capital investment.

8 Bibliography

AUS-MEAT, 2005. *Handbook of Australian Meat.* 7th Edition ed. Tingalpa DC: AUS-MEAt.

Kennedy, G., 2019. *P.PSH.1200 LEAP4Beef DEXA and 3D Sensing evaluation for markers guiding TEYS Primal cut paths.,* Sydney: MLA.

Kennedy, G., Maunsell, S. & Brennan, J., 2019. *P.PSH.0893 LEAP 4 Beef Sub project 1 - Automated Chine, button and fat trim proof of concept for the Striploin and Cube Roll,* Sydney: MLA.

Liddell, S., 2019. *P.PSH.1204 LEAP 4 Beef Cut information translation using carcass marking for TEYS automated beef deboning,* Sydney: MLA.

Maunsell, S., Kennedy, G. & Dickie, A., 2018. *P.PSH.0911 LEAP 4 BEEF Detailed Design Stage 2 - Develop high level design and layout concepts,* Sydney: MLA.

Nicholson, S., Cook, J. & Shirazi, M., 2019. *Investigating neural network algorithms for imaging points of interest identification,* Sydney: Meat and Livestock Australia Ltd.

Seaton, M., 2017. *P.PSH0741 LEAP 4 Beef - Vision development and preliminary concepts,* Sydney: MLA.

Trieu, W., Ford, M. & Shirazi, M., 2016. *JBS Dinmore Beef Rib Cutting,* Sydney: Meat and Livestock Australia.