final report

Project code: P.PSH.1204

Prepared by: S. Liddell
SCOTT TECHNOLOGY LTD (SCOTT)

Date published: 20 February 2019

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

LEAP 4 Beef cut information translation using carcase marking for TEYS automated beef deboning

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

This project aimed to review and test marking technologies on their ability to translate sensed cut information. In the proposed TEYS automated beef deboning process the carcase is predicted to move significantly during clamping and cutting process. Therefore it is proposed that the carcass can be marked prior to clamping and cutting and the cut location subsequently readily established with cost effective 2D cameras, without the need for a second x-ray unit and associated shielding.

The method employed was to mark the rib cage with the proposed marking device and analyse their effectiveness, manual visibility, automatic detection, the ability to be translated through the proposed TEYS automation process and wider saleability.

Spray marking was chosen as the best method to go forward. The lines and dashes were clearly visible to a person as well as being easily detectable with vision software. It was non-contact, resistant to sprays of water and the red and brown colours were assessed as being inoffensive to the end customer as it blended in with the meat and blood.

The rotary scoring lines were found to be problematic when vision software tried to find them. Therefore this option was discounted for future development.

Large spot drilling holes were found to be detectable but further vision software development is needed to guarantee it identifies them reliably. It would be an option for further development if spray marking is subsequently shown to be unsuitable.

Executive summary

In the TEYS automated beef deboning proposal, carcases will be x-rayed to find the required cut positions. However as the carcase will move position and shape significantly during clamping and cutting, the initial scan data will no longer hold true. Therefore it is proposed that the cut position is marked at the sensing station before the carcase moves. This will allow vision software to subsequently detect the shifted cut position, enabling the machine to follow the new correct cut path. If full automation is not desired by the customer, a cheaper manual cutting option is proposed. This will improve the manual cutting processes as butchers can follow the cut lines to both improve accuracy and reduce the amount of training required.

Different marking technologies were reviewed and assessed in their ability to mark beef carcases. From this review 3 selected methods were prototyped and tested on fresh beef short ribs. These methods were spray marking, rotary scoring and spot drilling. Photographs of the marked ribs were then analysed using vision software to see how easily the marks could be detected.

It was found that spray marking has the potential to mark beef carcases effectively, being easily visible to people and automatically detectable with vision software. This is the best option to develop in future projects. Rotary scoring was visible to people but was difficult for software to detect, therefore judged as not suitable for marking of carcases. It was concluded that it's possible to detect spot drilling using vision software, but further research into its reliability is required.

This report opens up opportunities for further development in beef automation and manual processing. The ability to re-find the sensed cut line is a crucial step in the success of automating beef carcase deboning. With the ability to find the cut position after clamping, it simplifies the way the machine is designed. This is because no effort is required to make sure the carcase doesn't move during clamping and cutting. The trade-off is that an extra process, with a consumable, is required. The impact on accuracy of the extra step would need to be considered versus alternative means such as re-referencing using carcass features or cutting from original clamp used in the sensing step.

Table of contents

1 Background

This research was undertaken to solve the problem of carcase movement during clamping and cutting in the proposed TEYS automated beef deboning process. As the shape and position moves significantly during this cutting process, carcase marking eliminates the need to re-scan the product each time cuts are made, but instead could utilise a cost effective 2D vision system to re-establish the correct cut path. This not only speeds up the process but allows the cut to be very accurate and reliable. Alternative means being investigated in other projects include re-referencing using carcass features or cutting from the original clamp used in the sensing step. Re-referencing introduces an error, yet to be quantified, and the feasibility of using the one clamp through the process is a topic of future research.

Carcase marking can also be used in a manual process. If the mark is visible enough to be seen and followed by a butcher, it opens up the opportunity for clients to invest in a cheaper system without automation. This would improve the accuracy of the cuts and reduce the amount of training required by the butchers, helping ease the struggle for industry to find skilled workers.

The marking of the required cut lines was simulated in this project, using fresh short ribs obtained from a New Zealand meatworks to carry out the tests.

2 Project objectives

The following objectives have been met:

1. Evaluated the ability for a marking device to mark the required cut marker locations on a beef side (hot and cold)
2. Identified if the markings are capable of translating the cut path information correctly and effectively through the existing TEYS process:
    a. Spray chill
    b. Pre-trim/pre-work
    c. Proposed cuts
3. Shown that the markings are able to be identified at each cutting stage as well as demonstrating that markings are acceptable to the saleable product in the locations proposed.

3 Methodology

The project is divided into the following milestones, forming the structure of the project.

3.1 Milestone 1 – Review marking technologies

Different marking technologies were reviewed and assessed based on the following criteria:

- Edible
    - Material is safe for human consumption
- Food safe compliant
    - Comply with all local regulations
- Manually detectable
    - Be visible to humans to follow cut lines
- Automatically detectable
    - Be visible to machine for automated cut lines
- Final product saleability
    - Have little effect on final product
    - Customer not put off from buying
- Durability through process
    - Remain readable after spray chilling and handling from workers
- Carcass stability
    - Not introduce carcass swing during the marking process
- Wash down
    - Be able to withstand a wash down environment
- Achieve cycle time
    - Technology is fast enough to mark lines within cycle time
- Cheap / Simple
    - Cost to build/buy
    - Maintenance costs
- Durable

  - Be able to withstand continuous operation, robot crashes, knocks with hoses etc.
- Available
  - Does the marking technology exist?
  - Can it be bought off the shelf?

These criteria were graded with a tick if it passed, a cross if it failed and a question mark if further testing was required. testing was required. Refer to

Table *1* for the evaluation matrix that compares all the technologies.

3.2 Milestone 2 – Cut location identification

Beef carcases were marked and tested to ensure they translate the correct cut path information for re-referencing. Fresh re-referencing. Fresh beef short ribs were used to test the marking technologies chosen to be further developed in milestone further developed in milestone 1. These were spray marking, rotary scoring and spot drilling. After the marking technology the marking technology was applied to the ribs, photographs of the marks were examined using vision software to observe vision software to observe how well the marks were detected. Its ability to be seen and translated into a virtual line for re-into a virtual line for re-referencing was analyzed and ranked as seen in

Table *2*.

Ideally the testing would have been done at a meat works with fresh beef carcasses. However for the purposes of this milestone having access to fresh short ribs should provide enough information into how effective the marking technology is at translating the cut path information. Using sprays of water was used to simulate spray chilling and was decided it was enough to simulate the process used in the meat works. The physical marking methods were not subject to water as this will have no effect on the lines.

3.2.1 Spray marking experimental method

Red and brown alcohol based Ink was applied to the rib set with photos taken at each stage shown below. To simulate the effects of spray chilling and pre-trim/pre-work, the ink was subjected to sprays of water and wiped after applying. A professional Iwata airbrush was used to spray the lines and is seen in Fig. *1*. This was used to replicate a complex spray marking system used in industry.

1) Spray with red and brown ink:
   a) Continuous line
   b) Dashed line
   c) Two dots
2) Wipe (pass finger over area) ink marks after two minutes
3) Spray ink marks with water
4) Wipe ink marks in 10 minutes after spraying with water

Fig. 1 - Iwata air brush used to replicate a spray marking device

3.2.2 Rotary scoring experimental method

Physical marking methods were tested and photographed. Rotary scoring was tested using four different saw blade types as seen in Fig. *2*Fig. *2*.

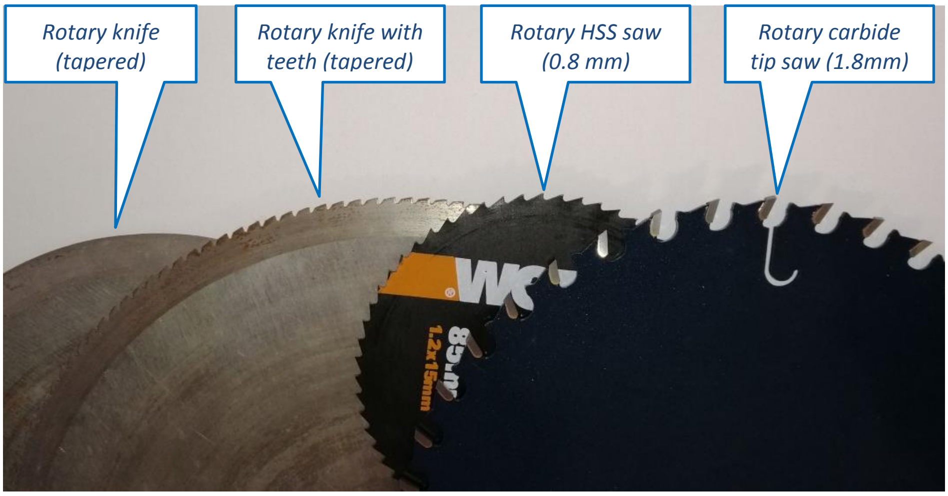

Fig. 2 - Different blade types used to test the rotary scoring marking method. Both knives had tapered edges that go to sharp point. The two saws remove material at the thickness of the tips

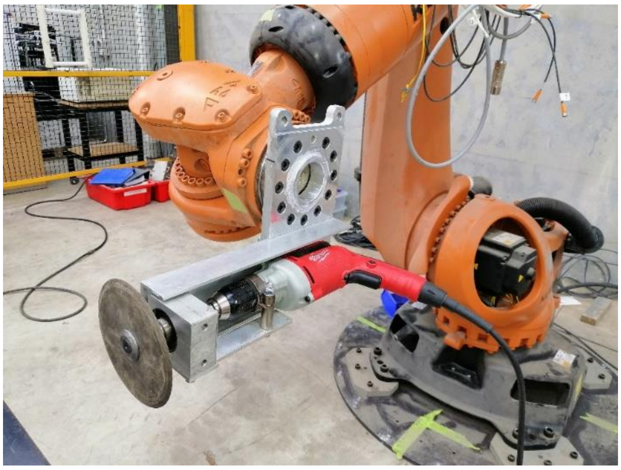

Fig. 3 - Robot spindle setup to test different blades. A robot was used for both safety and to produce a straight line

3.2.3 Spot drilling experimental method

Spot drilling was tested using 3 different sized drill bits. The spot drills were; 6.35x2.38mm centre drill, 3mm and 5mm drill bits.

Fig. 4 - Drill bits used for testing. [Left]: centre drill; [Centre]: 4mm drill bit; [Right]: 5mm drill bit

4 Results and Discussion

4.1 Milestone 1

4.1.1 Review of marking technologies

4.1.1.1 Inkjet printing

Ink-jet printing is when an electric charge causes a small amount of ink to be propelled out of a nozzle onto a substrate.

The advantage of inkjet printing is that food-grade ink is edible and approved by food safety authorities. Inkjet printers are primarily used to make complex small shapes and letters. Only a line is required for this marking purpose therefore a simpler spray marking technology might provide a simpler solution. Because of this reason this technique was not trialled.

4.1.1.2 Spray marking

Spray marking uses pressurised marking fluid to project a thin controlled line onto a surface. They are used in many industrial applications such as marking lines on belts and applying identifying spots on parts.

Advantages:

- Simple with no moving parts
- Doesn’t contact (carcase will not move during marking)
- Produces a clear line that is detectable manually
- Can use food grade ink
- Robust (could survive robot crashes)
- Easily washed down (no electronics)
- Proprietary part (minimal design required to get it working)
- Fast deposit rate

Disadvantages:

- Ink may run on wet carcases

- May not be resistant to spray chilling
- Precise distance away from product needed
- Uses ink as a consumable, ongoing cost
- Ink may still be visible to customer on final product

4.1.1.3 Roller marking

Roller markers are drums coated in ink that produce a label once rolled over an object. They are used in the meat processors to stamp company logos on the sides of carcases with food grade inks. This idea was adapted to create a line by using a thin wheel, felt fabric and a syringe as seen in Fig. *5* . The wheel runs over the product and leaves behind an ink mark.

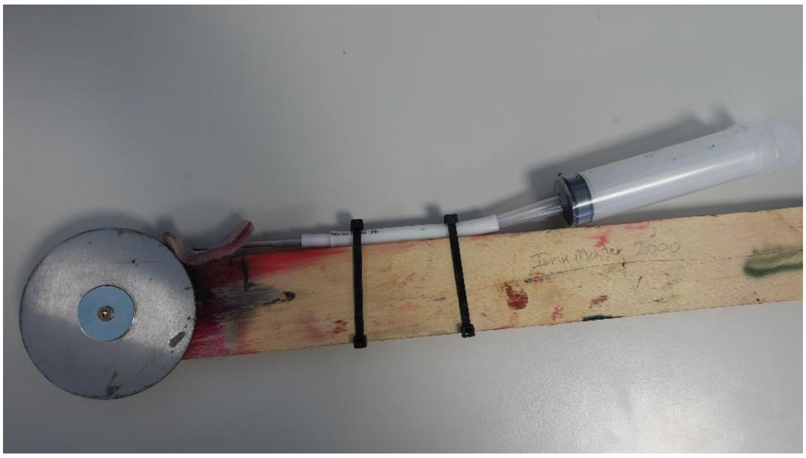

Fig. 5 - Roller marker concept prototype. A filled syringe is injected onto a felt pad which dispenses ink onto the wheel.

Advantages:

- Simple with only one moving part
- Produces a clear thin line
- Uses food grade ink
- Cheap to build
- Robust (could survive robot crashes)
- Easily washed down (no electronics)

Disadvantages:

- May move product as wheel needs to be in contact with ribs
- Ink may dry causing problems in mechanism
- Ink may run on wet carcases
- Need to apply constant pressure. Mounted on robot so air cylinders will need to provide correct force
- Uses ink as a consumable, ongoing cost
- Ink may still be visible to customer on final product
- Will become built up with fat and blood after continued use. Will need frequent cleaning

4.1.1.4 Laser engraving

Laser engraving is when laser light is focused to a single point to burn a visible mark in the material. There are 2 main types of lasers, CO_2 Lasers and fiber laser. They are frequently used to engrave metals, wood and plastics.

The company Trotec advertise their lasers can engrave labels on food such as fruits and vegetables, baked goods, meat and sausage (Trotec laser, 2019) . Another company Linx Printing Technologies, sells laser engravers designed to replace the ink stamping on animal carcasses with accurate and permanent laser coding (LInx printing technologies, 2019).

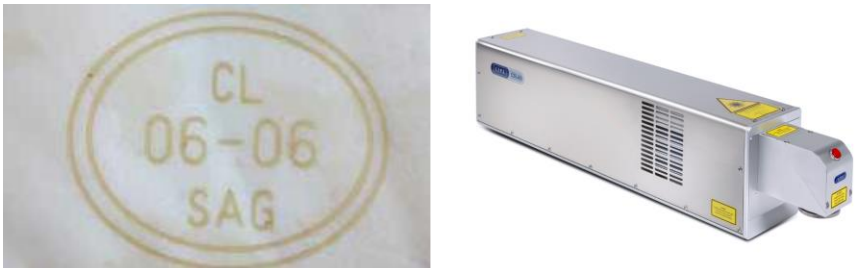

Fig. 6 - Product code produced from Linx laser marking on pig skin (LInx printing technologies, 2019).

Laser labelling of fruits and vegetables is permitted by a number of countries. An article (ScienceDaily, 2009) suggested that food laser etching has been licensed for use on a variety of fruits and vegetables and is being used in New Zealand, Australia, and Pacific Rim countries. It has been approved in Asia, South Africa, Central and South America, Canada, and the European Union.

In the U.S., the Food and Safety Authority (FDA, 2019) state that carbon dioxide laser light may be safely used for etching information on the surface of food under the following three conditions, one of which is that laser can only be used on citrus fruit. They state in section 179.43 of Title 21 "The carbon dioxide laser shall be used only for etching information on the skin of fresh, intact citrus fruit, providing the fruit has been adequately washed and waxed prior to laser etching, and the etched area is immediately re-waxed after treatment"

For the initial trials a section of loin was tested on an industrial laser cutter. Different power settings were tested from its lowest (200W) to highest (1000W) as seen in Fig. 8. 400W seems to provide the best compromise between visibility and damage to the product. 1000W scribes a line too big and deep which may affect its saleability to the customer.

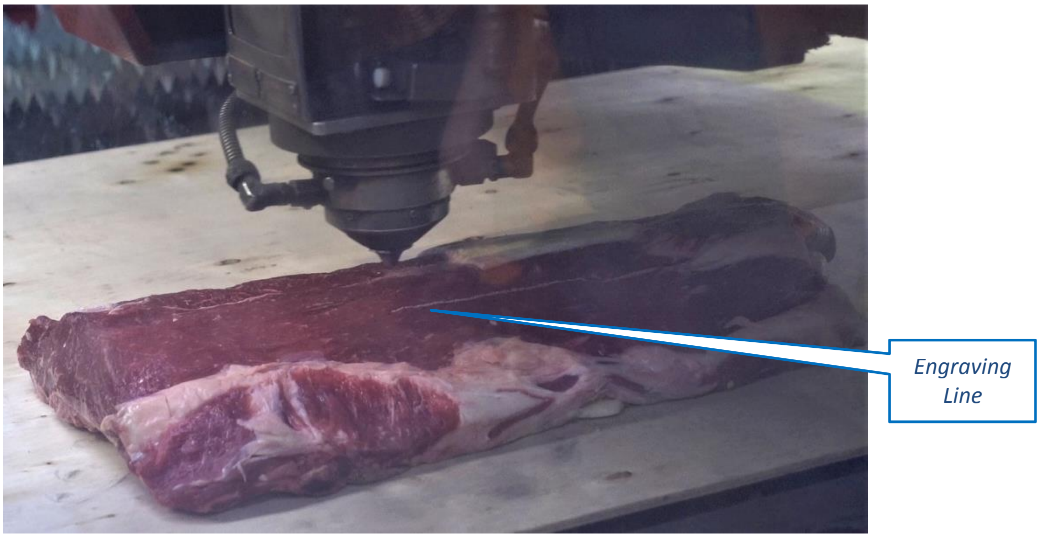

Fig. 7 - Amada FO-4020 NT Laser cutter used to trial engraving feasibility for meat

Fig. 8 - Laser engraving marks at different power settings on a section of beef loin

Fig. 9 - Laser engraving on bone at 200W. The line has good contrast against the white bone

Advantages:

- Doesn't contact (carcase will not move during marking)
- Produces a clear thin line
- Proprietary part (minimal design required to get it working)
- Fast engraving rate
- Mark remains stable after handling and spray chilling
- Uses no consumable

Disadvantages:

- Burns the meat (smoke could affect taste)
- Not FDA approved for meat (will need to seek it)
- Expensive equipment
- Not suitable for wash-down environment
- Fragile (may shatter lenses etc. if robot crashes, hit with cleaning hose)
- Burn mark may be visible to customer on final product

4.1.1.5 Spot drilling

Spot drilling was done by using a sharp drill at high speeds to peck a shallow hole into the bone. As only a straight line is required, two spot holes could be enough for a machine to create it. For a manual process, a series of holes could be drilled for the operator to follow.

Advantages:

- Simple (only requires spindle motor and drill bit)
- Produces clear circular mark
- Mark remains stable after handling and spray chilling
- Uses no consumable
- Cheap to build
- Edible and food safe
- Manually detectable
- Easily washed down
- Only need two spots to create a straight line for vision

Disadvantages:

- Produces bone chips
- Deforms and moves product when drilling
- Spot drill will be visible to customer if blade misses

4.1.1.6 Rotary scoring blade

Rotary scoring comes from the previous MLA project, Beef Scribing. However the idea is adapted so that only the top surface is cut or 'machined' away by making the depth of cut only a few millimetres. This would leave a visible line that could then possibly be seen by machine or workers.

Advantages:

- No consumables used
- Simple design (motor and blade)
- No external product added to carcase
- Edible and food safe

Disadvantages:

- Produces bone chips and dust
- May move product as blade needs to be in contact with ribs
- May be difficult to scribe at a shallow depth (high depth position accuracy required)

4.1.1.7 Dot Peening

Dot peening machines work by electromagnetically striking a carbide or diamond stylus against the surface of a part to be marked. This is mostly used for hard materials such as in automotive and aerospace industries.

As this doesn't change the chemical composition or add any material to the product it would be ideal for meat processors. However as bone and meat is very soft, this method would not be a suitable solution. Peening on flesh would give no visible mark, as it's too soft. The marks may only be visible on the bone and there wouldn't be enough contrast for workers or vision cameras to detect. For these reasons this idea was omitted and not trialled.

4.1.1.8 Water jet engraving

Water jet engraving is done by focusing a jet of water with abrasive media that etches the top surface of the material. They are used on hard materials such as steel and stone and leave a visible mark such as a part number.

Upon discussion with operators of water jet cutting machines, it was determined this technique was not possible for marking lines on carcases. Therefore this method was not trialled. The reasons are shown below:

- Minimum pressure 19,000 PSI, will cause to much damage
- Meat too soft, only used on hard materials like steel. Jet would simple cut material instead of etching the surface
- Usually use an abrasive media to help cutting properties. Not allowed in meat processor plants. Using no abrasive material will give very poor scribing results
- Will move product during marking
- Uses water (ongoing cost)

4.1.1.9 Pump markers

Pump markers are refillable, reusable pens that can be filled with edible ink. They are used in meat processor plants to write kill numbers and product information. These are ideal for writing quick notes on carcases but will not be suitable for industrial automation as the felt tip would experience wear and build-up of fat and blood. For these reasons this was not trialled.

4.1.1.10 Permanent quick dry edible ink

The ink used was food grade, edible ink. It's a food grade alcohol based dye that is used primarily for stamping logos and codes on the outside of animal carcases. It doesn't alter the fragrance or taste of the food and is fast drying.

The fast drying properties were tested and found that after 4 minutes the ink was dry and could not be rubbed off the carcase. It is expected that the marking would be post chilling, therefore testing was only done on "cold" product. These inks are commonly used by processors both on the kill floor and boning room therefore it is expected that marking could be done "hot" if required. Halal Ink is also available, which contains no alcohol. However this ink takes longer to dry.

Four different colours were trialled; pink, red, black and brown. These colours were chosen to be less noticeable to the customer as they could blend with the red muscle and blood. On the rib section there was enough contrast for all colours to be visible.

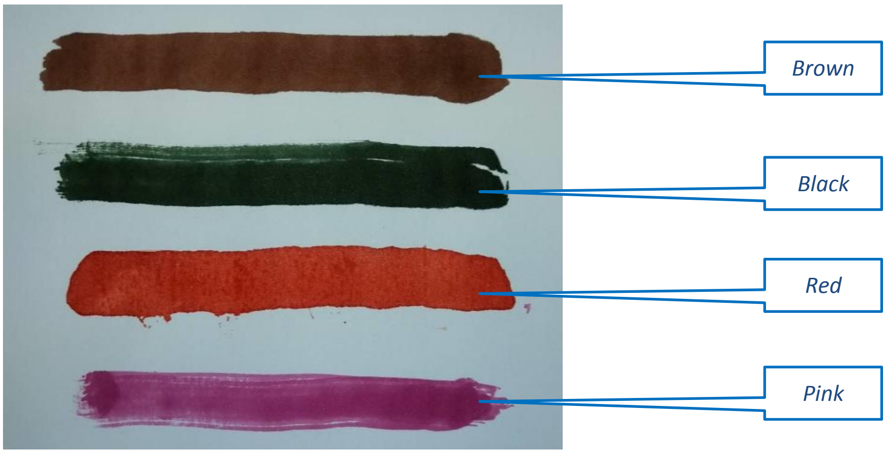

Fig. 10 - Different coloured edible inks on white background

4.1.1.11 Fluorescent Ink (visible under UV light)

The idea of using fluorescent ink is that the marking line can easily be detected in a dark room with black light and a camera. It also won't be seen by the customer so it will not affect the saleability of the product. As this can only be seen in a dark room with a UV black light, it is not suitable for manual detection.

Certain natural materials are fluorescent but transparent and can only be seen under ultraviolet light. Tonic water is an example of this and is frequently used in baking and jellies to make florescent foods for children. The quinine, the source of its fluorescence, is caused by phosphors that reflect UV light and make it glow bright blue (Morgan, 2017). However quinine is only safe in low doses and some people react poorly to it. This will not be acceptable for meat processor food safe requirements.

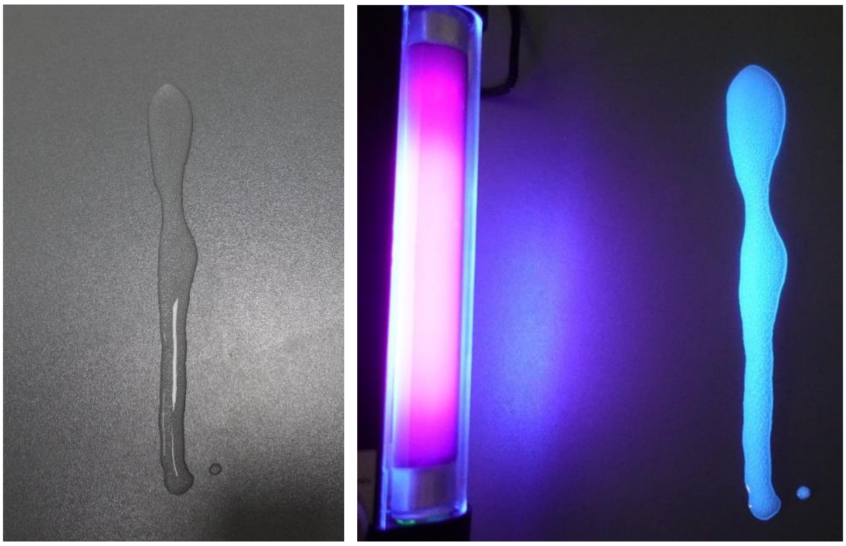

Fig. 11 – Tonic water under normal lighting conditions (left). Tonic water fluorescing under black light (right)

After testing it was discovered bones glow bright white under black light. This could be an issue as the majority of the abdominal cavity is bone and could draw contrast away from the line. The Tonic water as seen in Fig. *12* did not fluoresce enough to be seen under black light. A higher concentration of quinine may have produced better results, but would further compromise food safety.

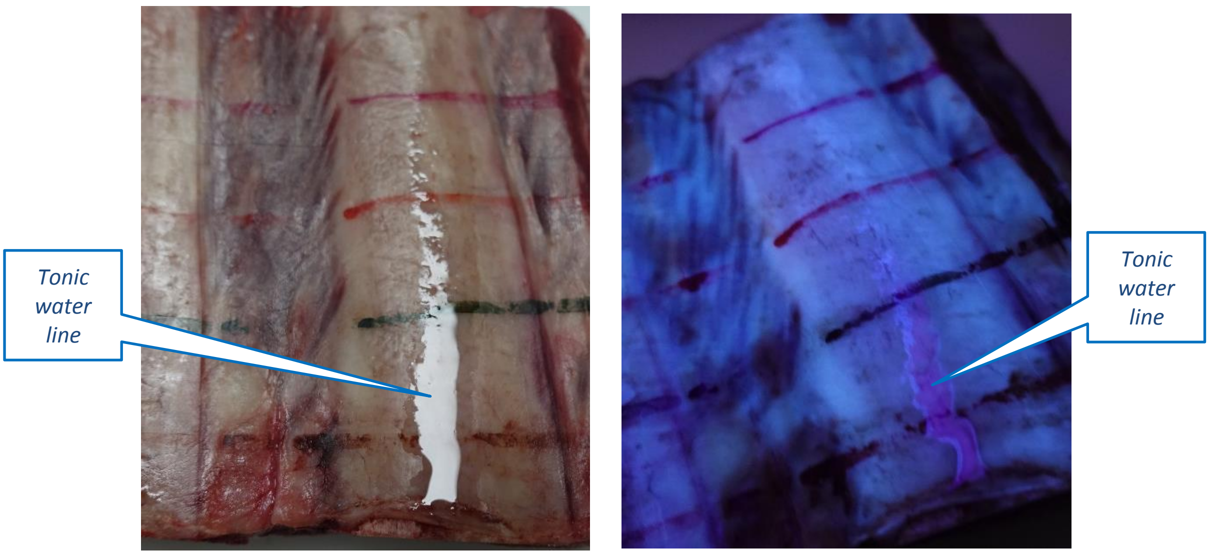

Fig. 12 - Tonic water line under normal light (left). Tonic water line under black light (right). The contrast between the bone and tonic water is not enough to machine detect. The fluorescence is inadequate.

Edible UV ink has been developed to print directly onto food for product tracking and security. Regal Packaging LTD had a product POLYtrust (Regal Packaging Ltd, 2019) which is an HACCP invisible ink that could be used for printing on food such as fruit and vegetables, meat and poultry, dairy products and eggs. It’s only visible once exposed to black light. However this ink recently became discontinued so is no longer available. It was also only available in cartridges meaning inkjet printing was the only option for this ink.

Fig. 13 - POLYtrust® HACCP invisible ink demonstrated on a banana in black light (RPL Regal Packaging Ltd, 2019). This ink is now discontinued.

4.1.2 Overview of marking technologies

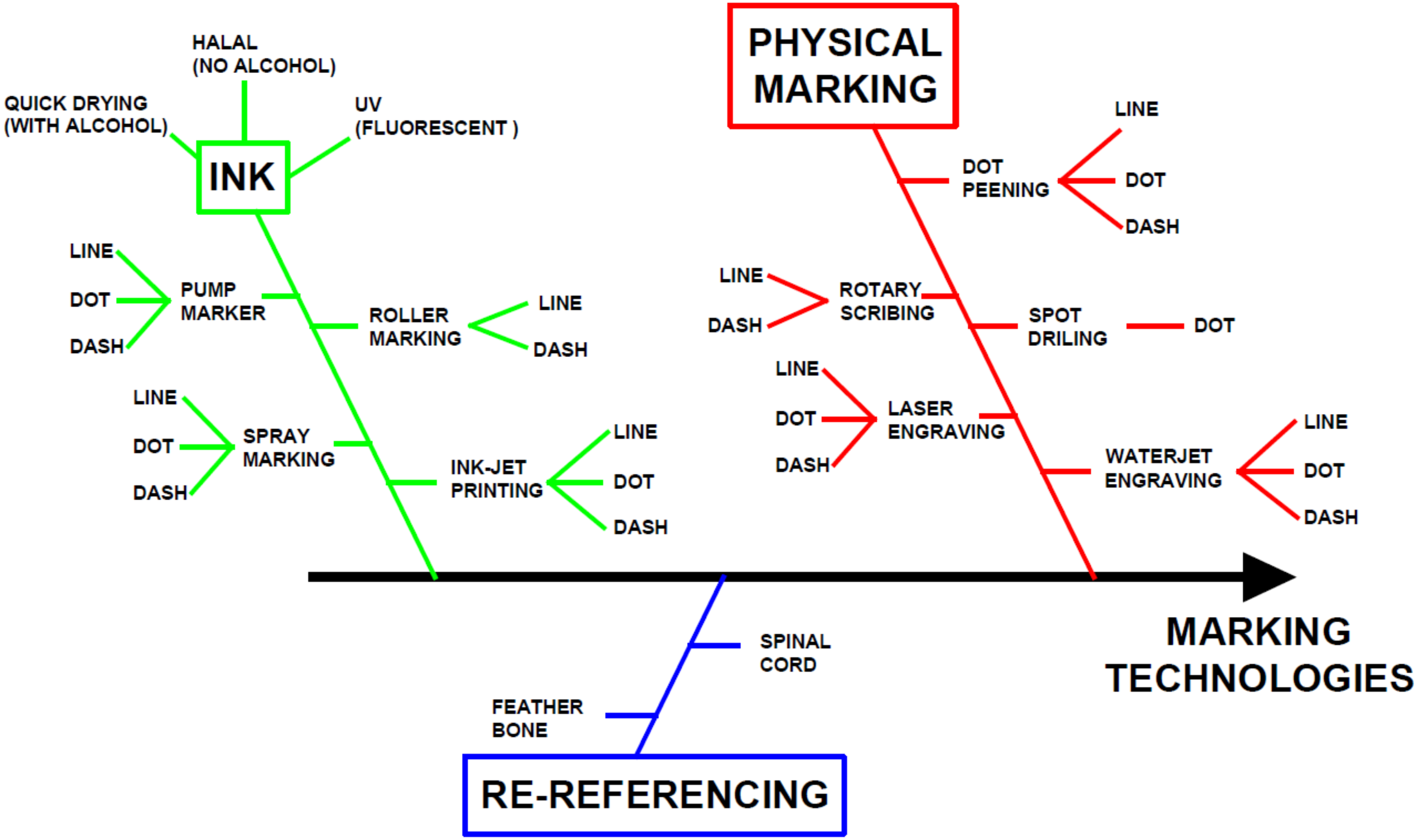

Fig. 14 – Proposed marking technology options

	Edible	Food safe compliant	Manually detectable	Auto detectable	Final product saleability	Durability through processes	Carcass stability	Wash down	Achieve cycle time	Cheap / simple	Durable	Available
Inkjet Printing	✓	✓	✓	?	?	?	✗	✗	?	✗	✗	✓
Spray Marking	✓	✓	✓	?	?	?	✓	✓	✓	✓	✓	✓
Laser Engraving	✓	?	✓	?	?	✓	✓	✗	?	✗	✗	?
Rotary Scoring Blade	✓	✓	✓	?	?	✓	✗	✓	✓	✓	✓	✓
Roller Marker	✓	✓	✓	?	?	?	✗	✓	✓	✓	✗	✓
Spot drilling	✓	✓	✓	?	?	✓	✗	✓	✓	✓	✓	✓
Dot Peening	✓	✓	✗	✗	?	✓	✗	✗	✗	✗	✓	✓
Water jet engraving	✓	✓	✗	✗	?	✓	✗	✓	✓	✗	✗	✗
Pump marker	✓	✓	✓	?	?	?	✗	✓	✓	✓	✗	✓
Fluorescent Ink (UV)	✓	?	✗	?	✓	✗	✓	✓	✓	✗	✗	✗

Table 1 - Overview of different marking technologies. They were assessed against important criteria needed to achieve the project objective.

4.1.3 Options for further research

Spray marking – Further research planned. Simple and robust solution that can be adapted for a meat processor environment.

Rotary scoring blade – Further research planned. Simple and robust solution. No foreign additives added to product.

Spot drilling - Further research planned. Simple and robust solution. Its effect on moving the product will need to be investigated.

4.1.4 Options discontinued or not currently being pursued

Inkjet printing – Not being pursued currently. Equipment is used for marking small labels and barcodes. Too complex for the purposes of making a line. May be investigated in future if spray marking gives issues.

Laser engraving – Not being pursued currently. Equipment very expensive and not suitable for wash-down environment. Also concerns about the smoke and burnt flesh affecting the taste. May be investigated in future if other avenues give poor results.

Roller marker - Research discontinued. Simple solution but not suitable as build-up of fat and blood on roller will cause issues.

Dot peening – Research discontinued. Not suitable for meat as too slow and will not provide enough contrast to be seen.

Water jet engraving – Research discontinued. Not suitable for meat. Will not etch as too soft.

Pump marker – Research discontinued. Not robust enough for automation and will experience build up at the felt tip.

Fluorescent Ink (UV) – Research discontinued. Food grade fluorescent inks have been discontinued.

4.2 Milestone 2

4.2.1 Carcase marking results

4.2.1.1 Spray marking

Spray marking with food grade inks, as per milestone 1, showed promising results. The ink was able to be applied to the fresh short rib and was dry to the touch almost immediately. After spraying with water to simulate spray chilling the line remained intact and did not wash off when wiped with a finger. The red and brown colour blended in well with the natural colour of the meat and blood, meaning its impact on saleability is low.

The effects of actual spray chilling in the meat works has not yet been tested.

Fig. 15 – Red Ink line, dash and dots sprayed on ribs. [Left]: image captured immediately after applying ink; [Right] image captured after wiping line at two minutes. Ink was dry before two minutes

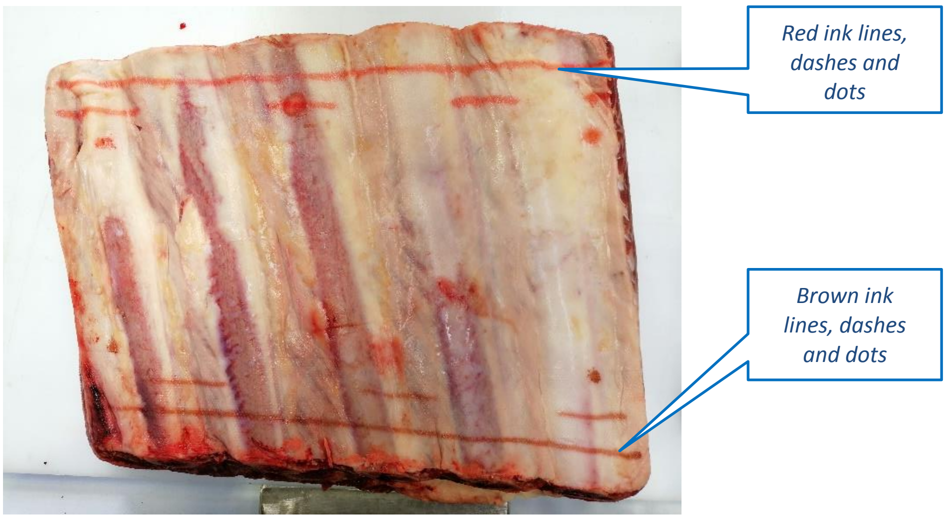

Fig. 16 – Red and brown ink lines applied to ribs. Both colours are manually visible.

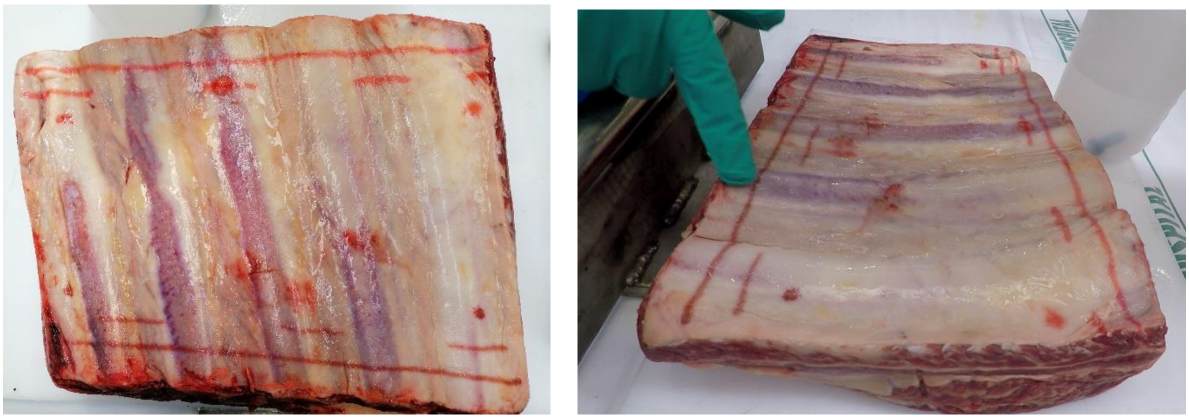

Fig. 17 – Ribs sprayed with water. [Left]: image captured after spraying with water; [Right]: image captured after wiping wet ribs after 10 minutes. Line is still visible and does not wipe off

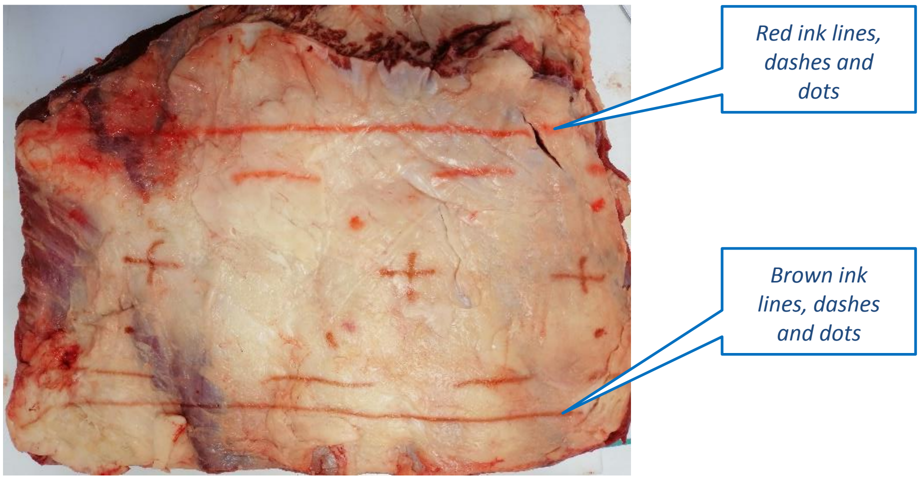

Fig. 18 – Red and brown lines marked on the fat side of the carcase. If the fat is not covered in blood there is enough contrast to see the marking lines

4.2.1.2 Rotary scoring

Using the different blade types showed that they produced similar results. The key difference is that the saws produced a thicker line, especially the 1.8mm carbide tip. This however doesn't have much effect on the lines ability to be detected manually. Since abdominal cavities undulate between each rib, the cut will have to be deep to produce a continuous line. The deeper the cut the more cutting force is experienced by the carcase which could introduce stability problems.

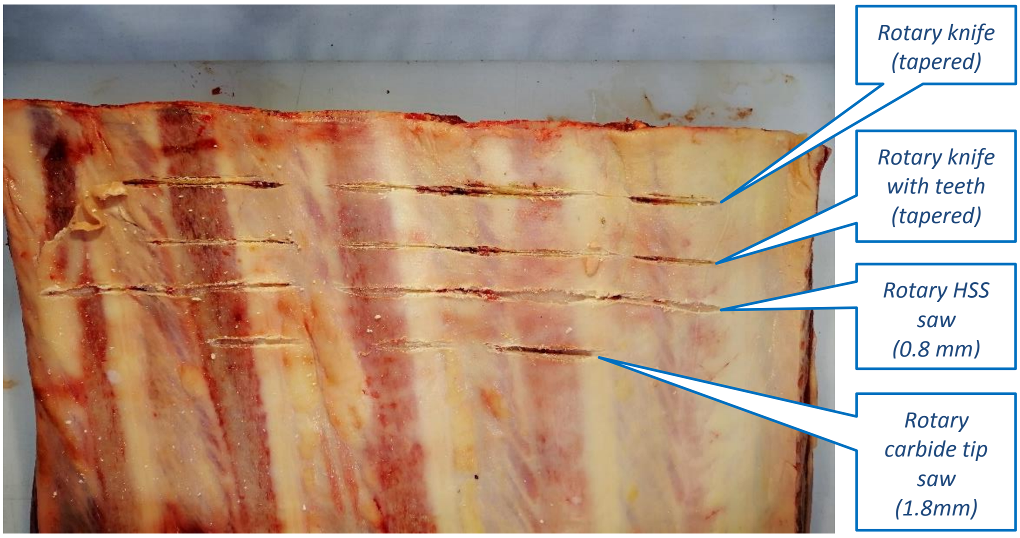

Fig. 19 - Scoring marks on rib set from four different test blades. All blades produced similar scribing results

4.2.1.3 Spot drilling

Different drill bits were assessed to see if the size of the hole effects the ability for vision to detect. The saw dust produced was blown off with compressed air. With the correct lighting the holes are visible as they become black in shade; increasing their contrast to the rest of the ribs. However they may be difficult for a worker to detect in a manual cutting process.

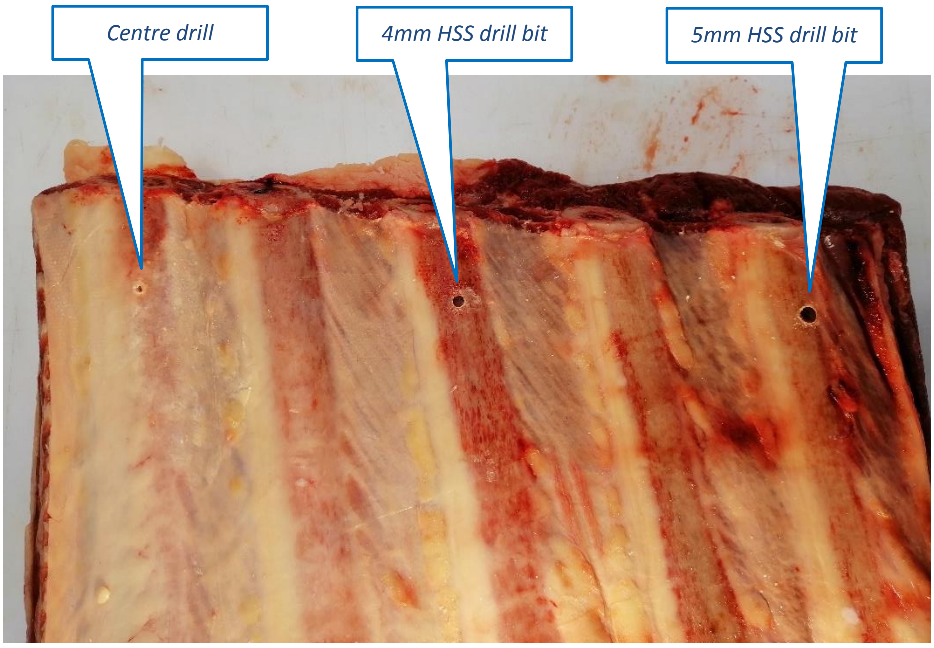

Fig. 20 – Spot drilling marks using 3 different drills bits

4.2.2 Vision analysis results

4.2.2.1 Spray marking

The spray markings, in both red and brown, were equally well defined and were both clearly visible against the inside of the rib cavity. The continuous lines were slightly more closely matched than the dashed lines, but this was only the extreme ends of the lines. However, the regular pattern of the intermittent lines allowed some good sanity checks that would eliminate false positives, such as blood streaks. The red dots were difficult to detect as there was not enough distinguishing features compared to blood spots, leaving it difficult to check for false positives.

Consistently spaced dashed lines would be the most ideal candidate for further trials. Dashes will also make the product more saleable as less ink is visible to the customer.

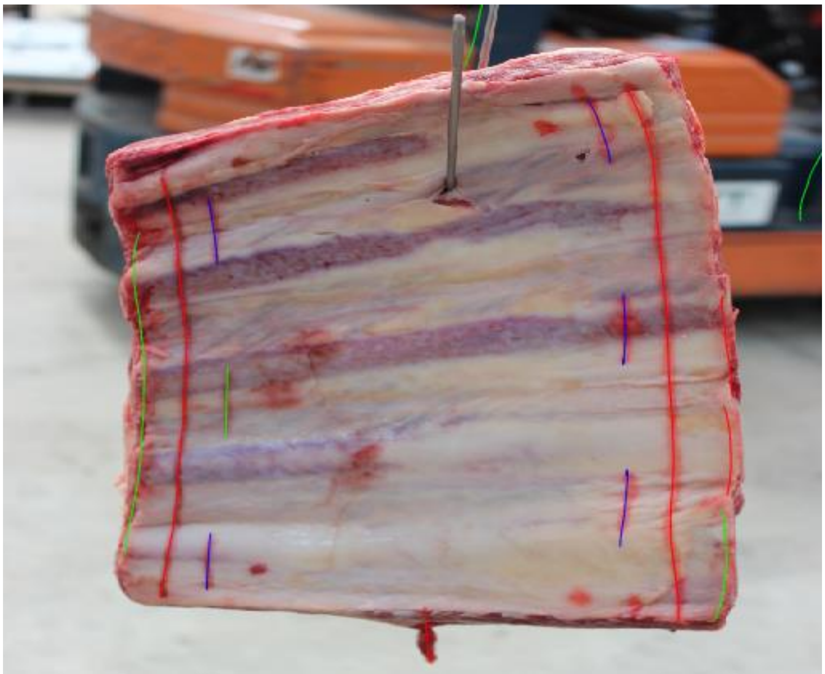

Fig. 21 – Preliminary results showing lines being picked up from vision software. Both red and brown lines were equally able to be detected and traced, with these colours being the least offensive colour for saleability. Both the continuous and dashed lines are able to be sensed. The dots proved to be more difficult to detect.

4.2.2.2 Rotary scoring

Vision algorithms struggled to determine the location of the scribe lines. The inconsistent width and appearance were the main reason for failure. The disappearance of the scribe markings in "low" areas led to disconnected, intermittent lines and an unpredictable pattern. This meant that sanity checks on the initial detection algorithms were unreliable in eliminating false positives.

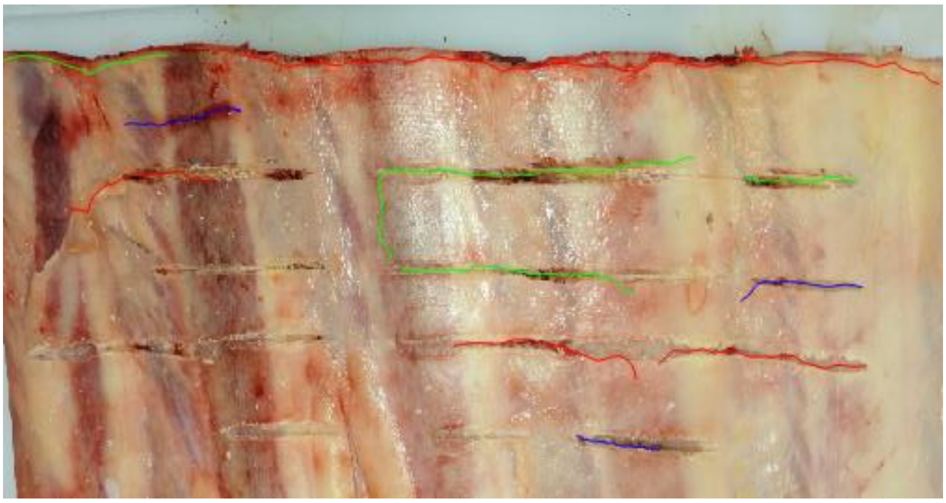

Fig. 22 – Preliminary vision results attempting to detect the rotary scoring lines. Inconsistent widths and intermittent lines were the main reasons for failure

4.2.2.3 Spot drilling

The two larger holes were visible in most images, the smaller hole was difficult to detect. It was clear that the angle of the lighting, camera and carcase surface would be very important in controlling the visibility of the holes. If multiple holes are required, e.g. to allow the original line to be adhered to in the presence of carcase deformation, controlling these viewing angles might be difficult across the length of the line. Further software development and testing in larger quantities is required to ensure the holes can be detected reliably.

5 Discussion

5.1 Evaluation of results

Marking Method	Marker Type	Vision detection (1-5)	Manual detection (1-5)	Process Durability (1-5)	Final Saleability (1-5)	Total (20)	Go/ No Go
Spray Marking	Red Ink	5	4	4	4	17	GO
	Brown Ink	5	5	4	4	18	GO
Rotary Scoring	Rotary knife	1	3	5	4	13	NO GO
	Rotary knife with teeth	1	3	5	4	13	NO GO
	Rotary saw HSS	1	3	5	4	13	NO GO
	Rotary saw carbide tip	1	3	5	4	13	NO GO
Spot Drilling	5mm drill	3	3	5	4	15	GO
	3mm drill	3	3	5	4	15	GO
	6.4x2.4mm Centre Drill	1	2	5	4	12	NO GO

Table 2 – Evaluation matrix of results from testing

Based on this evaluation matrix, spray marking with either red or brown ink appears to be the best option forward for developing a marking technology.

The rotary scoring blades tested showed it was visible to people but is difficult to detect for automation purposes. It was therefore was a no go.

Spot drilling was found to be automatically detectable, given the right conditions. Only the larger holes (5mm and 3mm) are able to be detected.

6 Conclusions/recommendations

This report provides evidence to suggest spray marking or spot drilling is suitable for translating the cut position in the TEYS process. These options should be used to develop future projects that require sides of beef to be marked for cut location.

Spray marking lines and dashes were able to be detected easily using software and was manually visible. Conversely the dots were difficult to see with vison as they merged in with the blood spots. The ink dried within two minutes and was resistant to rubbing and sprays of water. The impact of saleability was shown to be low if red or brown ink is used.

Rotary scoring was visible manually but the line was shown to be too inconsistent to detect with vision software. Therefore it was proven not to be a suitable solution.

Detecting large spot drilling holes was found to be possible if the correct lighting and camera angles were used. As it is difficult to achieve this consistently across the length of the carcase its development will only proceed if spray marking proves problematic.

7 Key messages

Spray marking is the most suitable option for marking of beef carcases. Provisional vision software was able to successfully detect these lines and dashes, meaning the cut information is able to be translated.

With this marking device, the TEYS automated beef deboning process is greatly simplified and will help improve yield. It also presents an opportunity for manual de-boning benefits reducing the skill set required by butchers.

Evidence has been provided in this report which creates a basis for continuing research in this area.

8 Bibliography

FDA. (2019, April). *CFR - Code of Federal Regulations Title 21, Sec 179.43 (21CFR179.43).* Retrieved from accessdata.fda.gov: https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=179.43

LInx printing technologies. (2019, November). *solutions/meat/*. Retrieved from linxglobal.com/en/: https://www.linxglobal.com/en/solutions/meat/

Morgan, S. (2017, April). */quinine-fluorescent-5344077.html*. Retrieved from sciencing.com: https://sciencing.com/quinine-fluorescent-5344077.html

Regal Packaging Ltd. (2019, November). */polytrust/*. Retrieved from polytij.co.nz: https://polytij.co.nz/polytrust/

ScienceDaily, A. S. (2009, November). *"Laser Etching Safe Alternative For Labelling Grapefruit"*. Retrieved from sciencedaily.com: www.sciencedaily.com/releases/2009/11/091103153752.htm

Trotec laser. (2019, October). *laser-machines*. Retrieved from troteclaser.com/en-nz/: https://www.troteclaser.com/en-nz/laser-machines/laser-engravers-speedy-series

9 Appendix

Not applicable.