Final Report

AUSTRALIAN MEAT PROCESSOR CORPORATION

Digitally signed steaks

Traceability - Primal to Steak / Steak to Primal Track 1 - Printed Primals using Countermark

Project Code
2021-1192

Prepared by
Alan Bell

Wessex Technology OEP Ltd
Portsmouth, United Kingdom

Date Submitted
27/04/2022

Published by
AMPC

Date Published
27/04/2022

Contents

1.0 Executive summary

The Australian Meat Processor Corporation (AMPC) put out a call on LinkedIn for companies that could meet the challenge of implementing Primal to Steak / Steak to Primal traceability. Wessex Technology (Wessex) had already developed Countermark and offered it as a potential solution. Initial discussions between AMPC and Wessex indicated two possible solutions, Track 1 explored directly printing traceability data on to the primal while still in the abattoir and Track 2 is based on secure labels and delivery paperwork used through the supply chain. The project investigated both solutions and this report describes Track 1 - labelling the primal. A separate report covers Track 2 – secure labels and delivery paperwork.

The project shows that existing ink, printers and software should be able to implement direct labelling of individual steaks with traceability data while the primal is still in the abattoir. During the project, the Wessex team discovered a potentially novel method of printing data onto primals.

2.0 Introduction

The purpose of the project is to evaluate if Countermark can facilitate Primal to Steak / Steak to Primal traceability of red meat in the form of primals distributed within the existing AMPC customer base including domestic and export markets.

This project will seek to address this challenge in two linked methods:

- Track 1 – By digitally signing the steaks in the Australian abattoir plant before they are cut from a primal elsewhere.
- Track 2 – By digitally signing every label used to control the shipment from the abattoir to the consumer and providing a web-based interface for food processors to use when producing steaks from primals.

The capability of Countermark, to accept data after creation and print, means that when the Animal Identity is known to the abattoir and can be matched to the "Kill number", it is possible to link the Animal Identity and breeding farm to the primal extending the traceability beyond the goal of the project, i.e. Farm to Steak / Steak to Farm.

Information about Countermark can be found in Appendix 1 – Countermark overview and at www.countermark.com

This report describes Track 1 and some elements of Track 2.

2.1 Directly labelling the steaks before the primal is cut and exported

The purpose of Track 1 is to investigate the possibility of directly attaching data to the primal in a way that would allow the consumer to check the origin of the meat sold to them in uncontrolled overseas markets and in the Australian market. The work consisted of attaching Countermarks to the primals and investigating the readability of the Countermarks as the primals went through a simulated journey, being held at different temperatures for durations that correspond to typical journey times, for both Australian domestic and export markets.

The work builds on work done by Frontmatec (Frontmatec.com, 2017) where similar inkjet printed characters were shown to stick to different meat surfaces on a beef and lamb carcass. This project used a similar ink as was used in this earlier work albeit with a different printer provided by the ink manufacturer. Data on drying time for the ink and the need to print on dry meat was taken from this report. All the primals used in this report were beef primals.

A Countermark directly printed onto the fat layer of a primal is shown in Figure 1.

Figure 1 Countermark inkjet printed on primal

2.2 Use of edible labels attached to the primals

An alternative to directly printing on the primals was developed using edible labels pre-printed with Countermarks attached to the primals. Printed edible material exists in other food industries, the materials initially selected include wafer paper, icing topper (from the home-baking industry) and vegetable material. The use of edible printable materials as labels for steaks or primals was chosen to minimise risk if the label was eaten. This stage of work was concerned with printability and robust reading of the Countermark rather than conventional food concerns, such as cost, impact on taste or introduction of adverse materials or contaminants.

Edible glue was used to attach the labels to the primals.

Images of the Countermarks on wafer paper and the lasered vegetables on a Cryovac wrapped primal are shown in Figure 2.

Figure 2 Laser marked leek and wafer paper labels on primal after Cryovac wrap, prior to journey

2.3 Primal preparation

Four primals had labels applied in an ABP Foods test kitchen, then Cryovac wrapped as per the normal primal shipping process. Three primals were transported to the XACT print test lab, printed, then returned to ABP Foods where they were Cryovac wrapped, again as per normal primal shipping processes. The seven primals were then transferred to Reading University (Department of Food and Nutritional Sciences) and either frozen, or stored in a chiller according to a pre-agreed schedule to represent the movement of primals through the supply chain. The primals were static during this freeze / refrigeration cycle with no attempt to replicate the effect of primals bumping or joggling against each other during transport.

The readability and adhesion of the labels were evaluated at different stages of the simulated journey.

2.4 Acknowledgements

Countermark is proprietary technology of Wessex and is protected by patents (Bell, 2015) (Bell, et al., 2014), (Bell, et al., 2015). Countermark (and the Countermark logo) is a Wessex trademark. All other trademarks used in this report are acknowledged.

- The authors would like the thank (in chronological order):
- Sean Starling and Stuart Shaw at AMPC
- Thomas Lauridsen of Frontmatec for advice on meat printing
- Declan McDonell of ABP Foods and his team at the Ellesmere (UK) plant for the primals and the use of their test kitchen
- Anthony Teal at Tealwood for laser marking the wafer paper and vegetables

- The teams at XACT Marking and Matthews for doing the printing and providing their printers and supplying the inkjet ink
- Dr. Sameer kalil Ghawi, PhD, MSc, PgD, BSc, MIFST, Department of Food and Nutritional Sciences, University of Reading for the use of their development kitchens and the guidance on food handling and processing
- EatMyFace and EatMyLogo for providing the edible printed labels (icing topper and wafer paper).

3.0 Project objectives

To develop and demonstrate to AMPC staff (and probably one Australian supply chain) the provider's approach to offering a cost-effective and robust Primal to Steak / Steak to Primal, traceability system, within a demonstration facility (i.e. not within an active supply chain).

4.0 Methodology for Track 1

Track 1 of this project is designed to select a range of edible marking including edible labels and direct marking. Then use these labels and marking to place a series of Countermarks on primals and measure the change in readability of the Countermarks as the primals progress from creation, to attachment to the primal and through the journey of the primal to the consumer packing.

Finally, observe the performance of the label materials and direct printing through these journey stages and make observations regarding the success or failure of the different materials.

4.1 Selection of edible labels

Icing topper and wafer paper are commonly used by the home baking fraternity for adding photos or messages to cakes. Test sheets were purchased online and printed with pdf files uploaded to the website.

4.1.1 Printed icing topper

Details	Information
Material	Icing sugar
Supplier	Eatmylogo.co.uk
Product	Icing topper
Icing ingredients (Eatmylogo.co.uk, n.d.)	Sugar, vegetable oil, glucose syrup, humectants (E420, E422), water, stabilisers (E413, E415), flavouring, colour (E171), emulsifier E472), acidity regulators (E270, E325), preservative (E202)
Edible ink ingredients (Eatmylogo.co.uk, n.d.)	Water humectant (E422), propylene glycol (E490), preservative (E202), food colours (E122-carmoisine, E133, E102-tartrazine, E124-ponceau), acidity regulator (E330)

A sample swatch pdf was created with different size Countermarks and submitted online for printing. The print quality of the received prints was tested by reading each Countermark with the Countermark App. All of the Countermarks read. It was difficult to physically separate individual labels (Figure 3) as the icing topper tended to crumble. The packaging was marked “DO NOT REFRIGERATE” – no reason was given for this instruction.

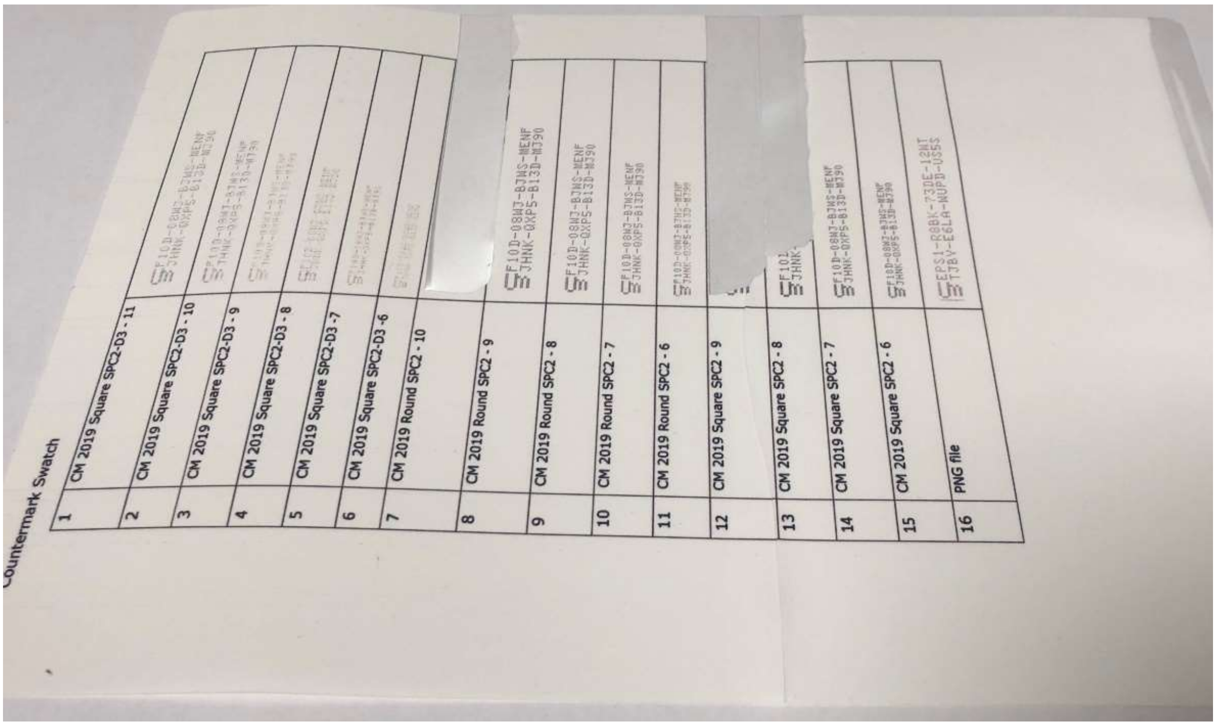


Figure 3 Icing topper test print crumbled when cut into individual labels

A separate preliminary test with printed icing topper placed on meat in a refrigerator showed the material had completely dissolved in 12 hours (Figure 4, Figure 5). It was decided to stop further testing with the icing topper.

Figure 4 Pre-test with printed wafer paper (left) and printed icing topper (right) stored in fridge

Figure 5 After 12 hours refrigeration the printed icing topper has completely dissolved

4.1.2 Printed wafer paper

Details	Information
Material	Wafer paper
Supplier	Eatmyface.co.uk
Product	Wafer paper (rice paper)
Wafer paper ingredients (Eatmyface.co.uk, n.d.)	Potato Starch, Water and Olive Oil
Edible ink ingredients (Eatmyface.co.uk, n.d.)	Water, glycerol E422, colour: brilliant black BN E151 (2,5%), sunset yellow E110* (0,8%), quinine yellow E104* (0,6%), 1.2 propanediol E1520

Wafer paper is widely used for creating printable designs (photos and greetings).

A sample swatch pdf was created with different size Countermarks and submitted online for printing with edible ink. The print quality of the received prints was tested by reading each Countermark with the Countermark App. Some of the smaller Countermarks failed to read electronically due to mottling on the surface of the wafer paper. A revised swatch was produced for the test based on the Countermarks that could be read by the Countermark app from the initial swatch (Figure 6).

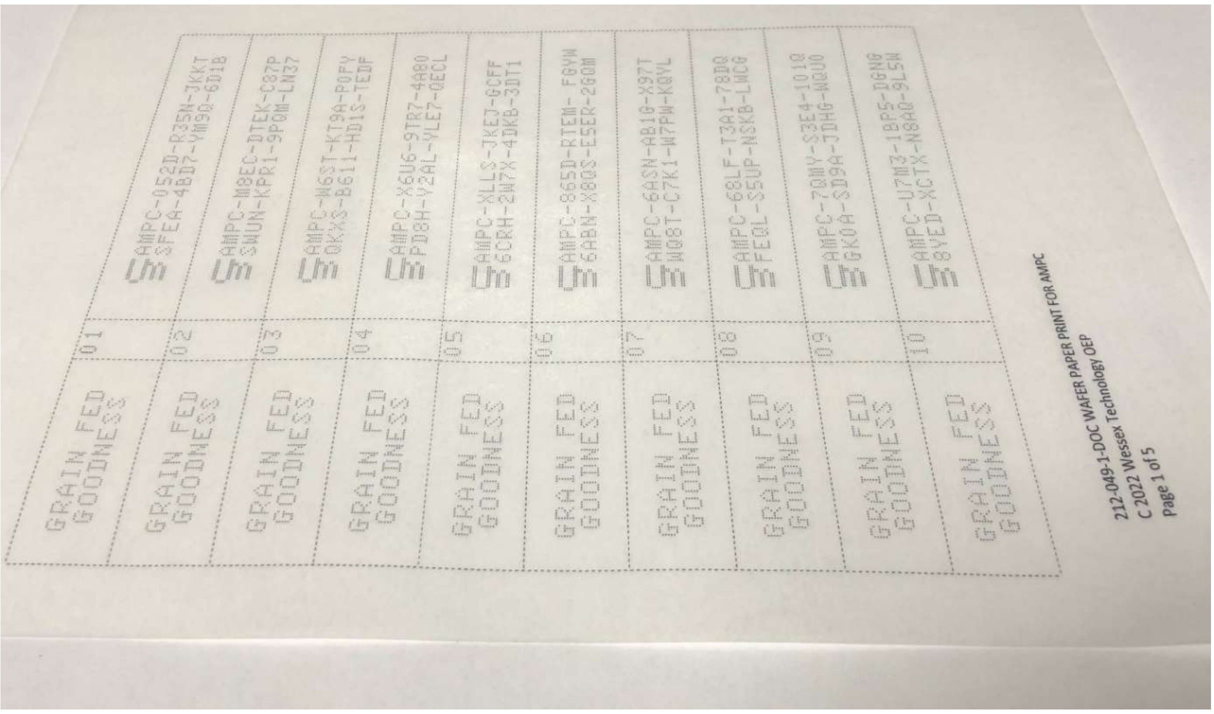


Figure 6 Printed wafer paper in strip format for labelling primals

4.1.3 Laser marked wafer paper

Details	Information
Material	Wafer paper
Supplier	Eatmyface.co.uk
Product	Wafer paper (rice paper)
Wafer paper ingredients	Potato Starch, Water and Olive Oil

A separate set of wafer paper labels was produced using infrared laser marking (Figure 7). The configuration caused holes corresponding to the Countermark dots in the wafer paper (Figure 8). This effect removed the need for ink on the wafer paper but would require that the wafer paper was placed over a contrasting background to get an acceptable Countermark app read performance.

Reading the Countermark with the laser marked wafer paper attached to the fat layer on a primal, would be challenging due to the lack of optical contrast between the wafer paper and the fat. It was decided to proceed with the test due to the simplicity of the material (low number of ingredients and no E-numbers).

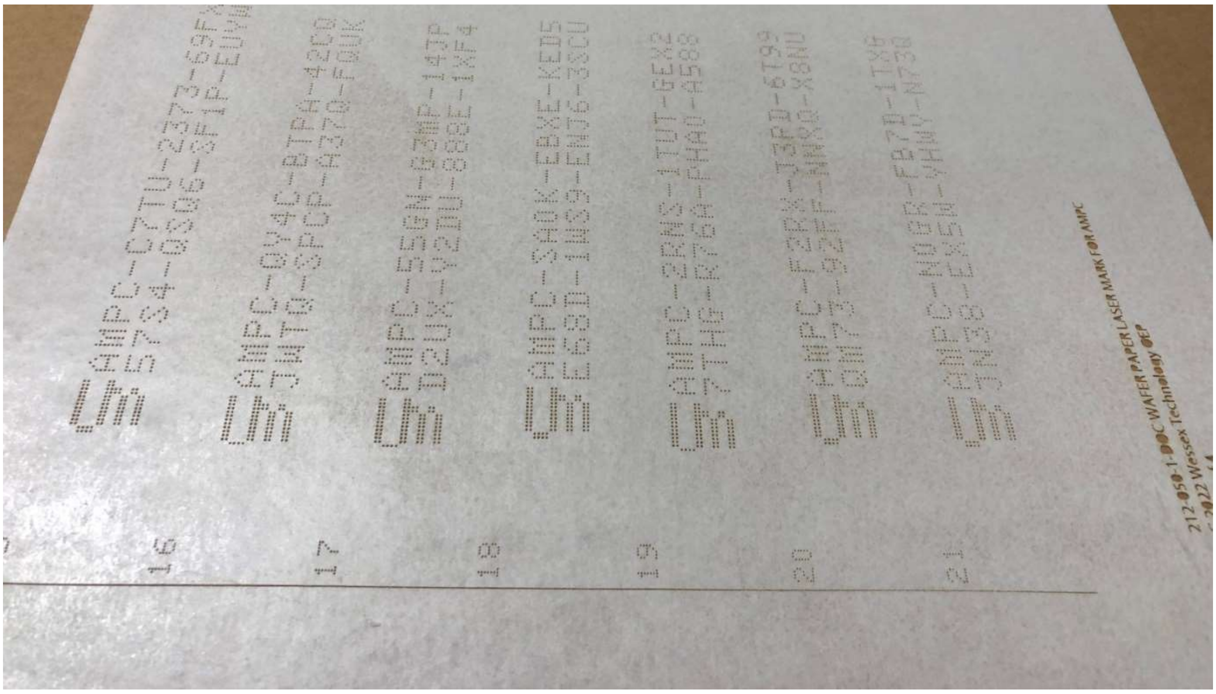


Figure 7 Laser marked wafer paper

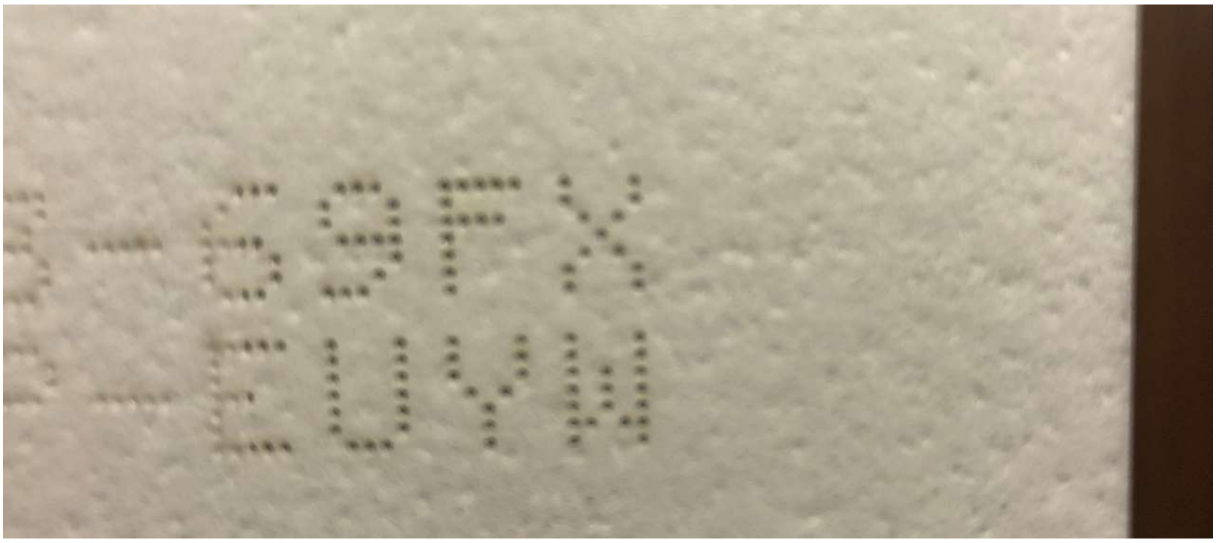


Figure 8 Holes in wafer paper created by the laser

4.1.4 Selection of vegetable labels

Details	Information
Material	Leek
Supplier	Local high street
Product	Leek
Ingredients	Leek

Laser marking vegetables is a relatively recent innovation, currently this process is used to show brand and harvest data (Packingeurope.com, 2018). For this project a range of vegetables were evaluated. This process comprised slicing or peeling, laser marking and performing test reads. Leek was selected due to its uniform thickness. The laser caused holes to form in the vegetable (as with the wafer paper).

Electronic reading of the laser marked leek was acceptable when the labels were produced when the labels were placed on a contrasting background (Figure 9).

Reading the Countermark in the intended application, attached to the fat layer on a primal, would be challenging due to the lack of optical contrast between the leek and the fat. However, it was decided to proceed with the test due to the simplicity of the material.

There may be separate concerns due to the risk of pathogens being introduced by using uncooked vegetables in a meat processing environment but this will require further study.

Figure 9 Evaluation of laser marked vegetable samples – leek layer chosen for uniform thickness

4.1.5 Edible glue for attaching labels to primals

Details	Information
Material	Edible glue
Manufacturer	Squires Kitchen
Product	Squires Kitchen SK Essentials – Edible glue. Order ref IN02A001-01-3A
Ingredients (Squires-shop.com, n.d.)	Water, preservative: acetic acid, thickener: cellulose gum

The authors are not aware of any existing edible glue that will bond wafer paper or vegetable material to the layer of fat found on a beef primal – so a cellulose-based glue (Figure 10) recommended for bonding wafer paper to the top of cakes was used. This glue was likely to not bond due to the moisture / exudate from the meat, however it was decided to check the impact of the glue on the label material.

The glue used is based on cellulose and is relatively viscous, making application easier.

Figure 10 Squires Kitchen edible glue

4.2 Inkjet printing Countermarks onto primals

Details	Information
Material	JM90001
Manufacturer (Matthewsmarking.com, n.d.)	Matthews
Product	Edible inkjet ink
Ingredients	Not known

Matthews Jet-A-Mark print head, part number DK8000+ 32V ALC with JM9001 edible ink (Figure 11) was used to do the inkjet printing.

The project goal was to print Countermarks no larger than 16 mm high and 180 mm long (Figure 12) – Countermarks of this size would fit on the edge of a steak giving one step ‘Primal to Steak’ traceability. The ink used for this project when printed on the Jet-A-Mark printer could print larger Countermarks (approx. 220 mm long). These larger Countermarks would be too long to fit on the edge of a steak but could still be used to test ink adhesion as the printed Countermarks were taken through the two simulated primal journeys.

The Matthews printer software was able to produce Countermarks using the standard Countermark font by Wessex Technology – no change was needed to the Matthews printer software to print Countermarks.

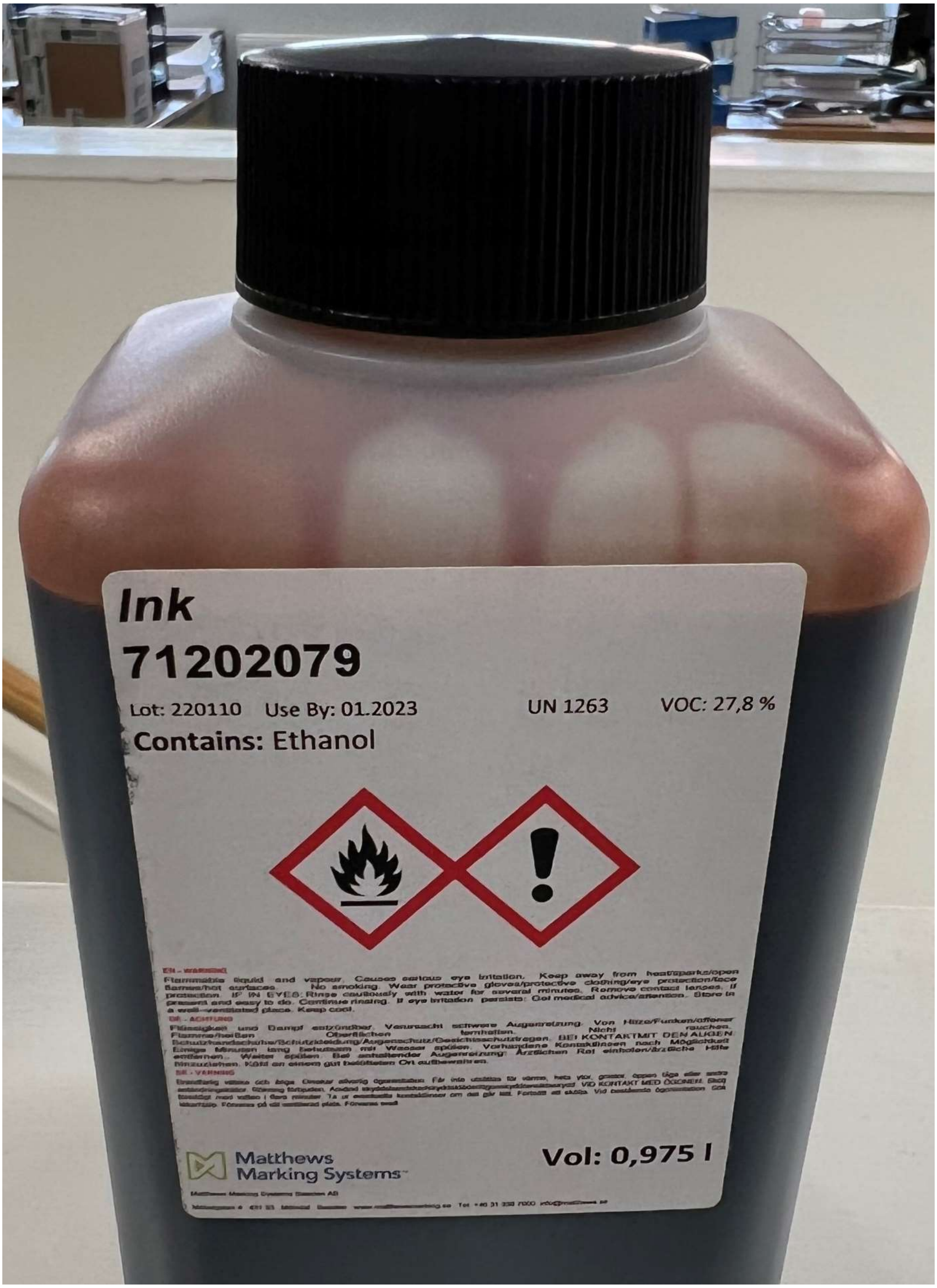


Figure 11 Matthews edible ink used for these tests

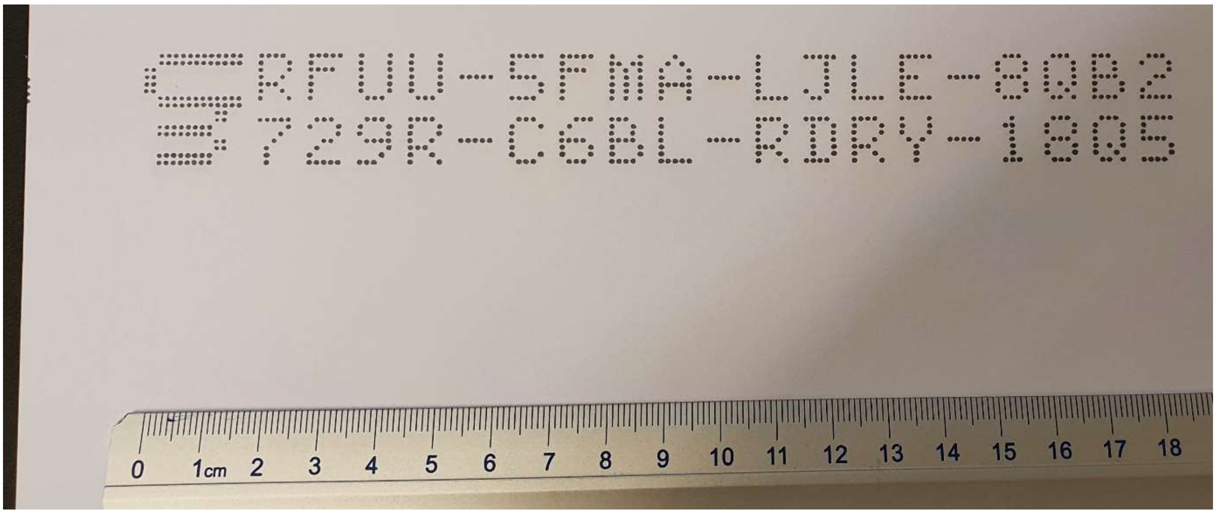


Figure 12 Anticipated inkjet printed Countermark size approx. 16 mm high and 180 mm long

Typically inkjet printing is used on packing lines and cartons where the printable surface is relatively flat and the print nozzle and the item to be printed are at a controlled distance apart, typically 8 – 15 mm. Frontmatec recognised this and suggest that the print nozzle is mounted on a robot arm so that it can be moved over the curved surface of the meat, maintaining a constant distance from the print nozzle to the meat.

It was not practical to integrate the printer into a food safe environment, so the Countermarks were printed in an industrial workshop setup for test prints on packaging and other industrial products.

Figure 13 XACT printer setup, note the exposed areas of primal for printing and foam block

The print environment at XACT included a belt conveyor (Figure 13), with the print nozzle pointing downward at the primal. It was necessary to adjust the height and position of the printer nozzle and the position of the meat on the tray between print runs. It was also necessary to adjust the position of the primal to ensure that the top surface of the primal was reasonably parallel to the belt, giving a consistent distance from the inkjet printer nozzle to the surface of the primal being printed. A white foam block was wedged under the primal for this purpose. It was also necessary to ensure the meat was completely dry prior to printing, this was done by dabbing the print area with absorbent paper.

Special operating methods were developed to prevent the lab environment being contaminated with exudate from the primal and to keep the primal from being exposed to the other material in the lab.

The printing method consisted of placing masking tape onto the primal Cryovac, feeding the primal past the print head and printing onto the masking tape. If the print quality was acceptable a scalpel was used to slice through the masking tape and the Cryovac just outside the area of the Countermark. The layer of masking tape and Cryovac in the region of the test print was peeled back to expose the surface of the primal to be printed. The primal was fed along the conveyor a second time, this time printing directly on the exposed surface of the primal.

Figure 14 Oversize Countermarks - the Countermark logo and three blocks of data could be fitted on the primal

4.3 The primals – thermal journey and Countermark evaluation

From Primal to Steak required that the primals needed to have representative journeys to test the performance of the attached Countermarks. Two journeys were used, one to replicate Australian domestic shipping and chilled maturation, the second to represent an export journey with the primal being frozen for one week prior to chilled maturation. These journeys are shown in Appendix 2 – Primal thermal journey.

It was originally planned to evaluate the labels at the stages below – some of the evaluation steps were omitted due to the condition of the meat or the label. The results of the tests and images of the labels at different journey stages are shown in section 5 of this document.

Journey stage/ evaluation	Print readability	Label adhesion	Cosmetic appearance
Abattoir – Labels before attach to primal	Visual appearance and readability	Adhesion process	Cosmetic appearance
Abattoir – after attach to primal	Visual appearance and readability	Label adhesion	Cosmetic appearance
Bagging of primal		Label adhesion	
Freezing of primal	Distortion after freezing	Label adhesion	
Defrost primal	Distortion after defrost	Label adhesion	
Unbagging of primal	Visual appearance and readability Does the ink transfer to the bag?	Label adhesion	Cosmetic appearance
After slicing	Visual appearance and readability	Label adhesion	Cosmetic appearance
Pack into supermarket polythene wrap package	Visual appearance and readability	Label adhesion	Cosmetic appearance
Leave in fridge for 5 days on an open plate	Visual appearance and readability	Label adhesion	Cosmetic appearance
Remove Label	Residual mark on meat	Residual glue / label on meat	Cosmetic appearance
Fry meat	Residual mark on meat	Residual glue / label on meat	Check for food appearance

4.4 Track 2 – frozen primals exudate test

The Track 2 part of this project does a mass balance exercise on the primals as they are sliced. Part of this Track 1 process is determination of the weight loss due to exudate that builds up in the Cryovac pack after defrost.

Each of the four primals used for the export / frozen journey was weighed, removed from their Cryovac packs, dried with paper towels and re-weighed. The Cryovac packs were washed, dried and weighed – note that the Primals 4 and 5 which were inkjet printed were double wrapped.

The four values of exudate loss can be considered indicative. No analysis was made into the reason for the variation.

Primal	Sealed weight	Dried meat weight	Cryovac weight	Indicated exudate
Primal 4	4.819 kg	4.619 kg	0.030 kg	0.170 kg
Primal 5	3.012 kg	2.951 kg	0.030 kg	0.031 kg
Primal 6	3.484 kg	3.379 kg	0.016 kg	0.089 kg
Primal 7	4.195 kg	4.016 kg	0.016 kg	0.163 kg

Figure 15 Primal 7 with exudate pooled under the Cryovac packaging – right-hand side of picture

4.5 Track 2 – labelling and weighing software test

The Track 2 part of this process provides label-based traceability of the primal, the packaged primals and the consumer packed steaks. Wessex staff took the opportunity to test the software on Primals 1, 2 and 3 in the Reading University test kitchen. This activity is noted here as the work was done on the labelled primals (Figure 16).

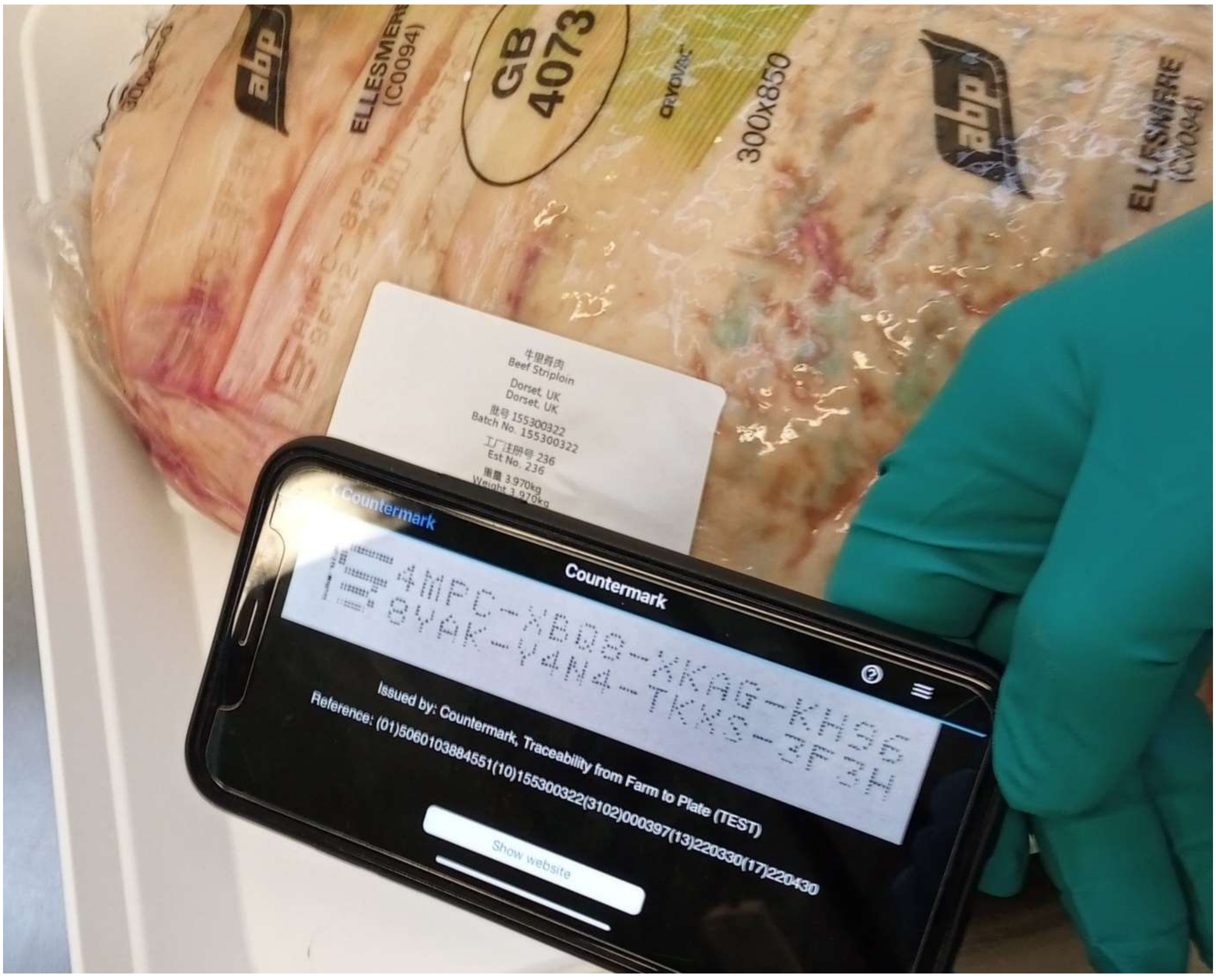


Figure 16 Track 2 software test, Countermarks app reads the data on the label, the leek Countermark in the background

5.0 Project outcomes

It was originally planned to evaluate the labels at the stages indicated in 4.3 however some of the evaluation steps were omitted due to the condition of the meat or the label. The results of the tests and images of the labels at different stages are shown below.

Readability has 4 levels of outcome as shown in the table below:

Readability	How readable is the Countermark?
3 (best)	Readable by app Fully readable by eye
2	Fully readable by eye
1	Top row partially readable by eye
0 (unusable)	Not sufficient information to retrieve the data held by the Countermark

5.1 Printed wafer paper

5.1.1 Reading result summary

Journey stage/ evaluation	Print readability		Label adhesion	Cosmetic appearance
	Non-frozen	Frozen		
Abattoir – Labels before attach to primal	3		NA	Good
Abattoir – after attach to primal	2		Label changed shape to that of the primal directly after application.	Glue leaching through label and curvature of primal impacted app reading (Figure 17)
After Cryovac packing of primal	2		NA	Glue leaching through label and curvature of primal and glossy surface of Cryovac impacted app reading (Figure 18)
Freezing of primal	N/A	N/A	NA	
After maturation, prior to unbagging	0	0,1	NA	Some blocks of print were totally blurred, other areas

Journey stage/ evaluation	Print readability		Label adhesion	Cosmetic appearance
	Non-frozen	Frozen		
				of print were readable by eye (Figure 19)
Unbagging of primal after maturation	0	0,1	Label peeled away easily	Some blocks of print were blurred, other areas of print were readable No ink attached to the Cryovac Different parts of the Countermark were either blurred or readable, in both cases this pattern appeared on fat (Figure 20)
After slicing	0	0,1	NA	Text transferred to meat stayed in place (Figure 21)
Pack into supermarket shrink wrap package	0	0,1	NA	
Leave in fridge for 5 days on an open plate.	NA	N/A	No labels in place	Non-frozen meat from primals 1,2 and 3 spoiled and was disposed of
Remove Label	NA	NA	No labels in place	NA
Fry meat	NA	0	No visible glue on meat	No visual indication of transferred ink remained on meat after frying (Figure 23, Figure 24, Figure 25)

Figure 17 Printed wafer paper glued to primal prior to Cryovac packing

Figure 18 Printed wafer paper after Cryovac packing

Figure 19 Printed wafer paper, some ink spread within wafer paper other remains in place

5.1.2 Printed wafer paper – observation – legible print ink migrated in to the fat

The primals that went through the 'Export' journey of being frozen then defrosted and matured showed that some areas of printed wafer paper had two behaviours. Some of the ink diffused through the label, other areas did not, but in both cases the ink transferred into the fat.

This gave either a dark stain in the fat on the surface of the primal (Figure 22), or completely legible text. This mechanism could form the basis of a new print on meat method – that is print high-resolution data onto a transfer tape, then with appropriate chemistry fix that ink onto the fat.

The code was human readable on the wafer paper and had not diffused. When this label was removed (Figure 20) an image of the code appeared on the fat (Figure 21), with legible characters even if a little faint. This process required the ink to migrate through the wafer paper, into the fat and become fixed in place. This occurred on a primal that had become inundated with exudate, indicating that a possible combination of the cellulose-based glue and some chemical within the exudate facilitated this process.

The ink-based characters on the primals disappeared after frying (Figure 25).

This result indicates that a new method of printing readable data onto the primal may be possible, by printing onto a suitable transfer tape that has the right chemistry to allow the ink to transfer to the fat permanently.

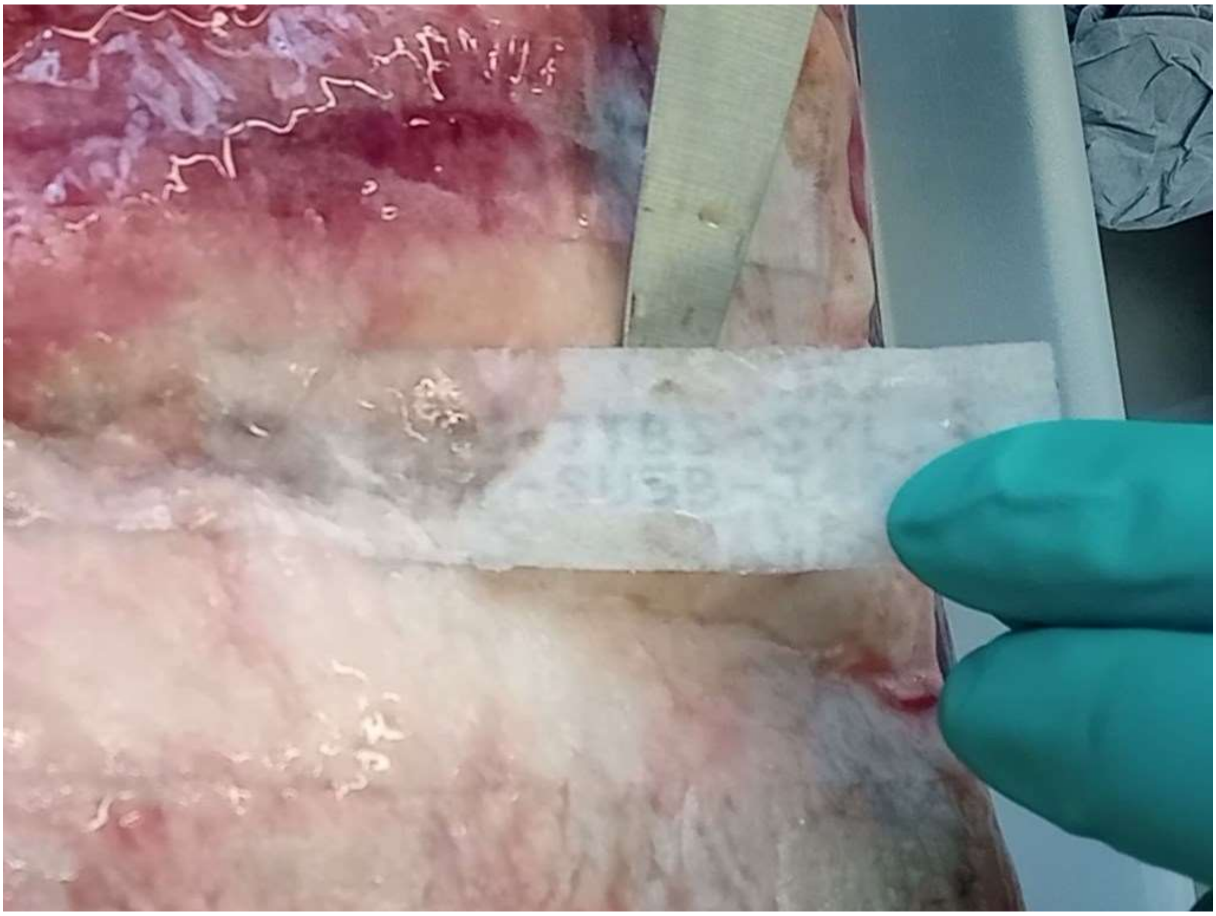


Figure 20 Peeling away the printed wafer paper

Figure 21 The ink fixed to the fat under the wafer paper

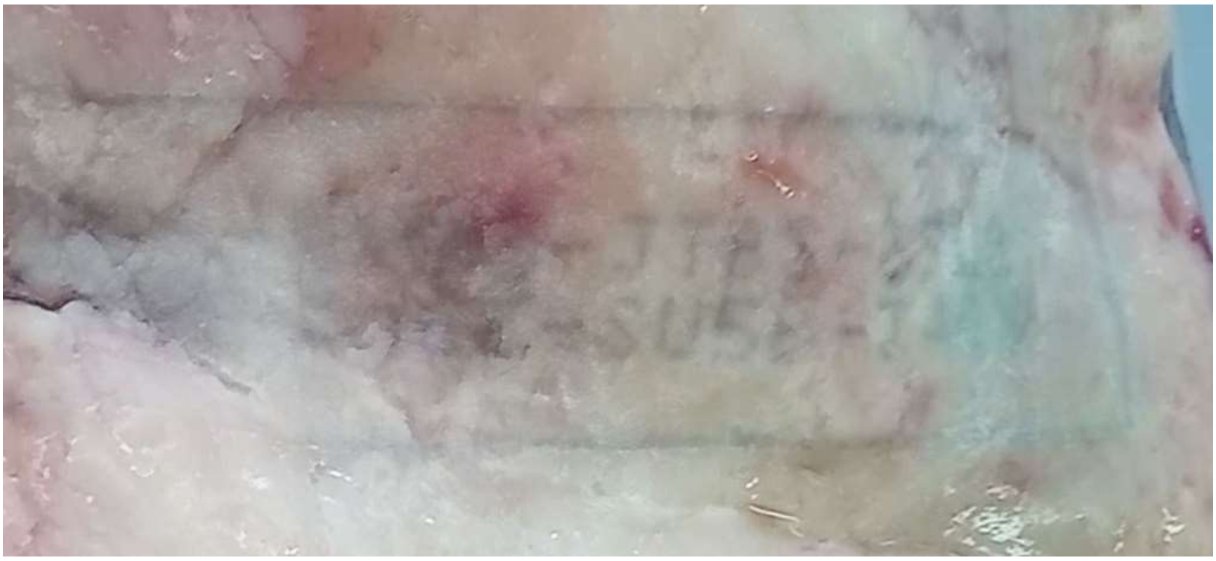


Figure 22 Detail of the imprint on the meat due to ink transfer from the wafer paper

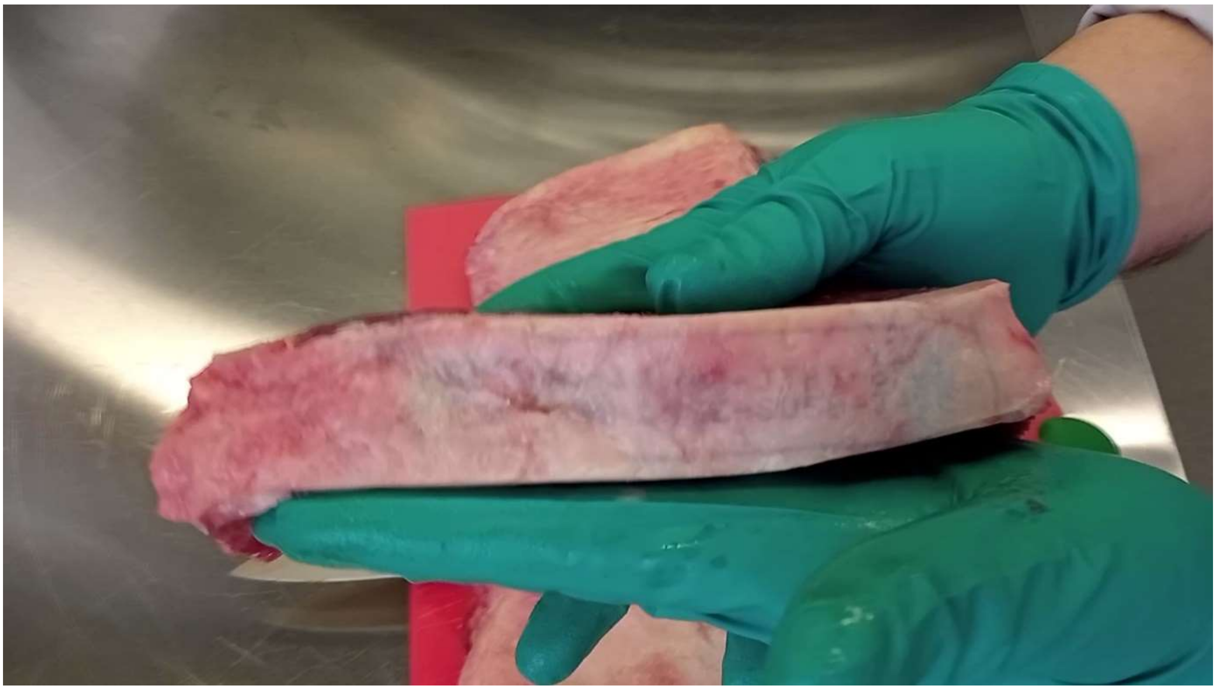


Figure 23 Steak cut from primal with faint Countermark imprint

Figure 24 Steak with faint Countermark in the frying pan

Figure 25 Steak with faint Countermark after frying – the Countermark was not visible

5.2 Laser marked wafer paper

Laser marked wafer paper maintained its physical integrity through the process but the contrast ratio was insufficient for reliable human or machine reading.

5.2.1 Reading result summary

Journey stage/ evaluation	Print readability		Label adhesion	Cosmetic appearance
	Non-frozen	Frozen		
Abattoir – Labels before attach to primal	3		NA	Good (Figure 7)
Abattoir – after attach to primal	2		Label changed shape to that of the primal directly after application.	Glue leaching through label and curvature of the primal impacted app reading (Figure 26)
After Cryovac packing of primal	2		NA	Glue leaching through label and curvature of primal and glossy surface of Cryovac impacted app reading (Figure 27)
Freezing of primal	NA	NA	NA	
After maturation, prior to unbagging	0	0,1	NA	Data was unreadable and hard to distinguish by eye, the labels had become a reservoir for the exudate, (Figure 28) this did not

Journey stage/ evaluation	Print readability		Label adhesion	Cosmetic appearance
	Non-frozen	Frozen		
				appear to happen with the printed wafer labels
Unbagging of primal after maturation	0	0,1	Label peeled away easily	Data was unreadable and hard to distinguish by eye until label removed from meat and rinsed under running water (Figure 29) and held against a contrasting colour (glove)
After slicing	NA	NA	NA	NA
Pack into supermarket shrink wrap package	NA	NA	NA	NA
Leave in fridge for 5 days on an open plate.	NA	NA	NA	NA
Remove Label	NA	NA	NA	NA
Fry meat	NA	NA	NA	NA

Figure 26 Laser marked wafer paper before packing

Figure 27 Laser marked wafer paper after Cryovac

Figure 28 – Laser marked wafer paper acting as a reservoir for exudate

Figure 29 Laser marked wafer paper washed after removal from primal – characters legible with contrasting background

5.2.2 Laser marked wafer paper – observation – material robust and data was retained

The wafer paper remained intact during the process. However, the code formed by the holes was only visible with an appropriate background, in this case the green gloves.

The individual dots created by the laser process may have created a pathway for the exudate to gather under or within the laser marked wafer paper.

5.3 Laser marked leek

Laser marked leek maintained its physical integrity through the process, but the contrast ratio was insufficient for reliable human or machine reading.

5.3.1 Reading result summary

Journey stage/ evaluation	Print readability		Label adhesion	Cosmetic appearance
	Non-frozen	Frozen		
Abattoir – Labels before attach to primal	3		NA	Good (Figure 7)
Abattoir – after attach to primal	2		Label arched away from fat, resumed normal leek shape directly after application.	Curvature of label impacted app reading (Figure 30)
After Cryovac packing of primal	2		NA	Curvature of primal and glossy surface of Cryovac impacted app reading (Figure 31)
Freezing of primal	NA	NA	NA	

Journey stage/ evaluation	Print readability		Label adhesion	Cosmetic appearance
	Non-frozen	Frozen		
After maturation, prior to unbagging	0	0,1	NA	Some data was unreadable and hard to distinguish by eye (Figure 32)
Unbagging of primal after maturation	0	0,1	Label peeled away easily	Data was unreadable and hard to distinguish by eye until label removed from meat and rinsed under running water (Figure 33)
After slicing	NA	NA	NA	NA
Pack into supermarket shrink wrap package	NA	NA	NA	NA
Leave in fridge for 5 days on an open plate.	NA	NA	NA	

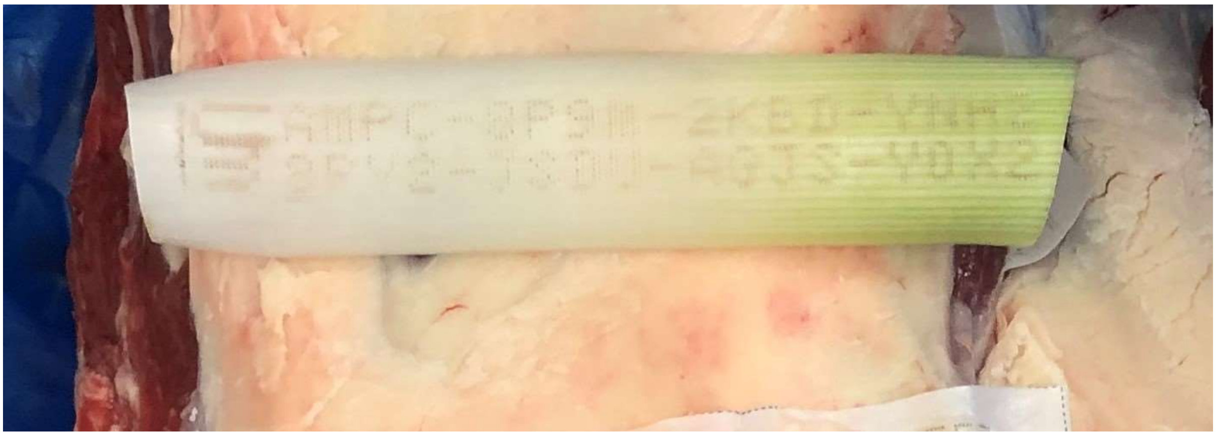


Figure 30 Laser marked leek prior to Cryovac processing

Figure 31 Laser marked leek after Cryovac

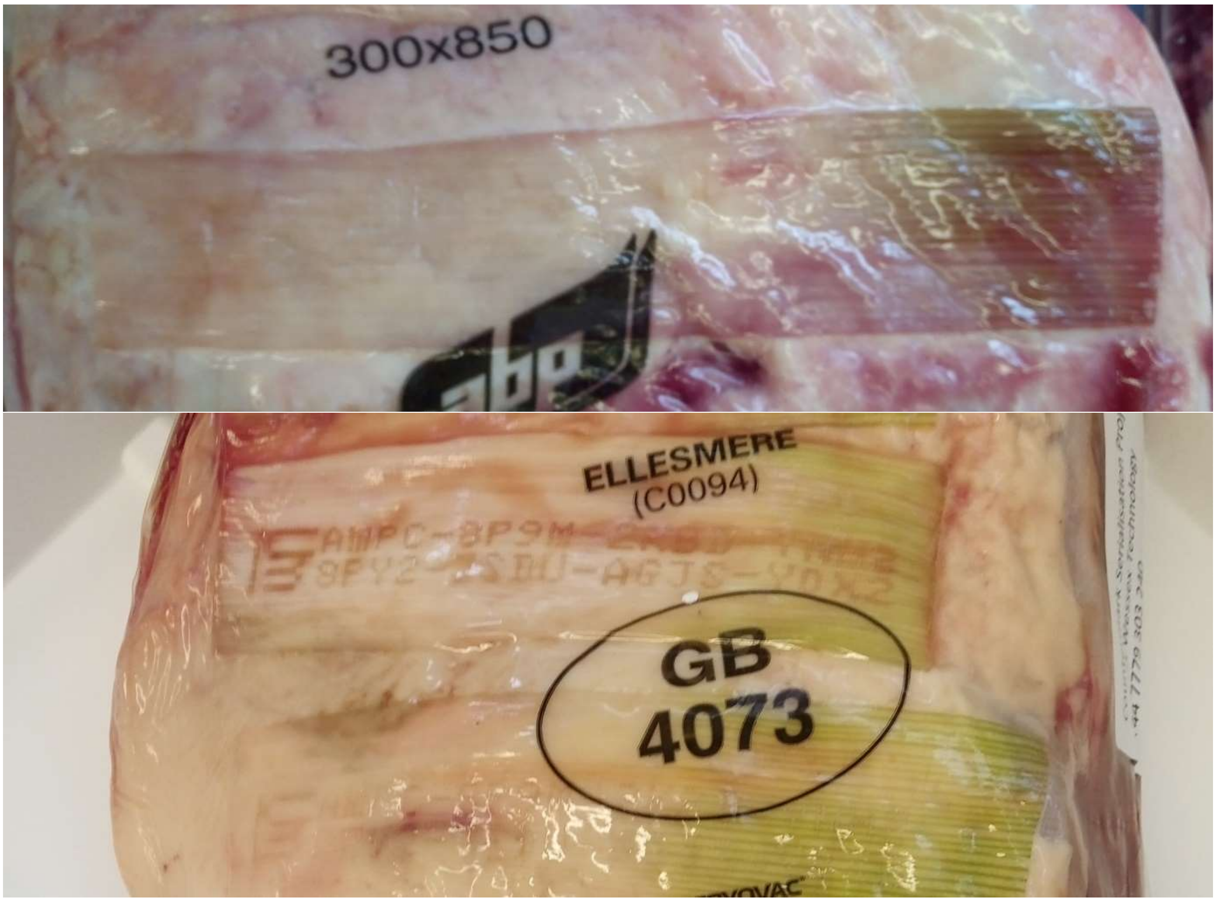


Figure 32 Laser marked leek after Cryovac freezing and maturation – two separate primals

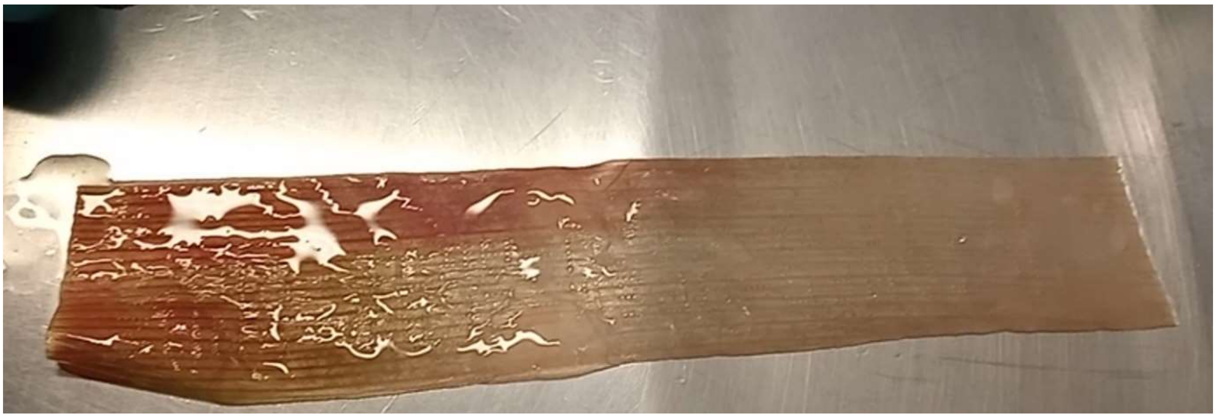


Figure 33 Laser marked leek washed after removal from primal – laser created holes are hard to see

5.3.2 Laser marked leek – observation – data marking is not reliable

The leek remained intact during the process however the Countermark formed by the holes was only just visible.

The individual dots created by the laser process appear to have closed (Figure 33).

5.4 Inkjet printing

The partial Countermarks remained visible and identifiable throughout the journey, and only disappeared when the meat was fried.

Two separate rub tests (finger in rubber gloves and paper towel with moderate pressure – Figure 36) showed that the ink adhesion was good. When the ink did appear to detach, it may have been the top layer of fat (with the ink attached) that was removed rather than the ink moving away from the fat.

The Countermarks were too large to be printed on or read from the edge of the steak. Groups of characters that would allow a manual read were visible throughout the process – these numbers would be sufficient for manual Countermark entry to recover the associated data.

The smallest complete Countermark achieved by the inkjet printer (Figure 39) was human readable after completing the export (frozen) journey.

5.4.1 Reading result summary

Journey stage/ evaluation	Print readability		Label adhesion	Cosmetic appearance
	Non-frozen	Frozen		
Abattoir – Labels before attach to primal	3		NA	Test prints on paper were fully readable (Figure 12)
Abattoir – after attach to primal	2		NA	Partial Countermarks were too distorted and too much information missing to read electronically (Figure 14)

Journey stage/ evaluation	Print readability		Label adhesion	Cosmetic appearance
	Non-frozen	Frozen		
After Cryovac packing of primal	2		NA	Countermark data fully visible through Cryovac (Figure 34)
Freezing of primal	NA	NA	NA	NA
After maturation, prior to unbagging	2	2	NA	Countermark data fully visible through Cryovac
Unbagging of primal after maturation	2	2	Ink attachment survived rub test (Figure 36)	No ink attached to the Cryovac (Figure 35)
After slicing	2	2	NA	Partial Countermark readable on wider steak (Figure 37)
Pack into supermarket shrink wrap package	2	2	NA	Text fully visible through simulated supermarket packing
Leave in fridge for 5 days on an open plate.	2	2	NA	Text fully visible through simulated supermarket packing Non-frozen meat from primals 1,2,3 spoiled and was disposed of
Remove Label	NA	NA	NA	NA
Fry meat	NA	2 – 0	NA	Countermark characters fully visible prior to frying, characters disappeared when the fat was fried (Figure 38)

Figure 34 Inkjet printed Countermarks after Cryovac

Figure 35 Inkjet printed Countermarks after freezing, maturation and removal of Cryovac

Figure 36 Rub-test using paper towel to check adhesion of ink to fat

Figure 37 Inkjet printed Countermark prior to frying

Figure 38 Inkjet printed Countermarks on steaks after frying

Figure 39 Smallest Countermark 220 mm long - along the primal.

6.0 Discussion

6.1 Edible labels

Using printed labels allowed higher resolution printing, and therefore smaller Countermarks, than was possible with direct printing.

The labels were able to conform to the shape of the meat and did not break up if the meat changed shape.

The labels can be produced ahead of time, away from the production line, so may be easier to integrate into a food processing environment than the inkjet printer.

It was discovered that the edible inks migrated from the printed wafer paper label to the fat during the journey, which may give an opportunity for future development.

Using laser-marked wafer paper and leek had the advantage of introducing few new ingredients.

The laser-created holes in the labels lost some contrast through the journey and may not be stable.

The edible labels were not able to be reliably bonded to the steak with the edible glue that was selected for the trial. This would warrant further study as there may be better options available.

Overall, the technology transfer from home baking to meat preparation needs further development to resolve the issues found as described above.

6.2 Inkjet printing – direct ink on meat

Printing ink directly onto the meat has some advantages and could allow traceability data printed on the primal in the abattoir to be read and used by the consumer to access data about the steak.

6.2.1 Positive indications

The process showed that the ink had good adherence to the meat through the journey from abattoir to consumer.

The ink is already in use in the meat processing industry.

Use of the Countermark font and data export format has demonstrated that software integration between Countermark and the Matthews printer was successful.

6.2.2 Inkjet Printer capability

The printing system needs to be set up for safe operation in a food processing environment, rather than the demonstration environment used for this study.

The large character size created with this ink and printer means that single row Countermarks would need to be developed together with bespoke reading software. This single row Countermark could then be used to create a pattern of Countermarks along a primal - giving one Countermark per steak.

It may be possible to reformulate the ink to allow smaller 2-row Countermarks to be printed, avoiding the need for bespoke Countermark software.

The tests did show that it is possible with current ink, printer and Countermark software to produce 220 mm long Countermarks that would act as a digital signature for the fat layer of beef primals; this larger Countermark would allow buyers of the primal to be certain of its origin and age.

To achieve consistent printing across a primal, the distance between the print head and the primal would need to be kept constant during printing. Primal measuring technology would be needed as well as a robot arm to achieve this - the arrangement would be required for controlled dot placement.

Frontmatec had already demonstrated the need for dry meat. This was evident during the current study and the moisture on the primal may have been atmospheric condensation due to chilled meat on a rainy day.

An additional problem to resolve is that the ink has a drying time of the order of minutes. This would need to be reduced and/or managed for use in a production environment.

6.2.3 Reading limitations

The direct-print Countermarks (of brown dots on a brown surface) showed a low contrast ratio. Different inks may be available that improve the contrast to allow easier reading of the Countermark, whether by app or by eye.

The noise in the background (i.e. natural colouration and patterning in the meat) was not perceived to be a particular problem for the evaluated Countermark. For enhanced Countermark read performance, it would be advantageous to have a cleaner, smooth cut fat surface for the printing.

A study of the app data when reading the Countermarks printed on fat indicated that the codes were generally too irregular:

- code was miss-shaped – distortion in meat as it was cut, and the packaging, caused a distortion in the code shape
- the dot positions were not well controlled which may have been caused by the variable distance from the printer nozzle to the meat

6.2.4 Read-after-print

A camera system to perform a read of the printed Countermark is essential to ensure that Countermarks are readable before they leave the processing plant. This would detect potential printer faults or other defects in the printing process.

6.3 Software integration

Both direct printing and labels will need some elements of the software process identified in Track 2 to capture and manage the Countermark and meat data.

7.0 Conclusions / Recommendations – Track 1

7.1 Conclusions

7.1.1 Direct printing

Existing ink, print and data technology comes close to the project goal of adding machine readable data onto steaks whilst still part of the primal – this would allow consumers to run app-based verification on their purchases. This approach would require no further technology changes for the downstream food producers. The remaining technical challenges include:

- Understanding how the ink / printer combination used in these trials can be enhanced to allow smaller Countermarks and / or developing single row Countermarks.
- Developing the primal printing system – with the capability of either moving the primal past a static print head or moving the print head past a static primal. Either approach would need to include integrated primal drying and drying time for the ink on the primal. Both of these approaches would also need to accurately measure the 3-dimensional profile of the primal to allow the print head to be kept at the optimum distance from the primal surface.
- Evaluate other inks that may be available:
    - to give a better optical contrast for the automated reading software
    - to operate with a shorter drying time
    - to allow print on damp meat

7.1.2 Edible labels

The edible labels selected by Wessex remained intact for the early part of the primal journey but need further development – they have not shown to be suitable for full Primal to Steak traceability but could be used to validate primals for part of the journey, from abattoir to consumer packing plant. Countermarks can also be used with existing labelling technology to digitally sign the primals allowing primal buyers to fully verify the primal product they are purchasing.

7.1.3 Transfer printing

The migration of printing ink from the printed wafer paper to the meat should be investigated further. The use of transfer labels to add data to the steaks would allow high resolution, colour information to be added to the primals. Much technology (edible inks, cartridges, print electronics and software) exists for this type of printing,

The chemistry of how the ink transfers and fixes to the fat on the primal is outside of Wessex expertise, and other parties should take this further.

7.2 Recommendations

The recommendations are limited to technical issues only, secondary issues such as unit cost or customer acceptability are not addressed.

7.2.1 Data system integration

For the complete system of using Countermarks to digitally sign primals to be implemented, it would still be necessary to deploy the software discussed in the Track 2 report.

7.2.2 Fix the small print problem

The ink and print head combination need investigating to resolve the printing limitations so that smaller Countermarks that can fit on the edge of a steak can be printed.

7.2.3 Investigate any other inks that would have a better contrast ratio

Investigate alternative inks to determine the best contrast ratio between ink and background (fat). This may include fluorescent inks – inks that are invisible under normal lighting and appear under UV light will have improved read performance and may be more acceptable to some customers.

7.2.4 Prepare the primal with a more uniform fat layer

Investigate the uniformity of the background over many primals.

7.2.5 Investigate the ink migration process that was discovered.

This was an unexpected effect, that would need a study of the chemistry involved to understand if it is a usable method for putting high-resolution data onto primals.

7.2.6 Investigate primal profiling technologies

Mechanical and sensor integration is required to allow the print head to track the primal surface.

7.2.7 Implement a read-after-print system for the selected printing technology.

This form of vision system is commonly used in industry and it should be considered here to ensure good printing.

7.2.8 Test on sheep and goat meat

AMPC is responsible for maintaining the interests of sheep and goat producers. Primals from these animals should also be tested.

8.0 Bibliography

Bell, A. J., 2015. *Monitoring moveable articles.* USA, Patent No. 9010654.

Bell, A. J., Robinson, M. & Chen, G., 2014. *Machine Reading Of Printed Data.* Japan, Patent No. 6006315.

Bell, A. J., Robinson, M. & Chen, G., 2015. *Machine Reading Of Printed Data.* USA, Patent No. 9104936.

Eatmyface.co.uk, n.d. *https://eatmyface.co.uk/a4_printed_sheets.htm.* [Online]
Available at: https://eatmyface.co.uk/a4_printed_sheets.htm
[Accessed 20 April 2022].

Eatmylogo.co.uk, n.d. *https://eatmylogo.co.uk/product-category/toppers/.* [Online]
Available at: https://eatmylogo.co.uk/product-category/toppers/
[Accessed 20 April 2022].

Frontmatec.com, 2017.
https://www.mla.com.au/contentassets/b6e72d8b5c52447d9f662fdc61124594/p.psh.0904_final_report.pdf. [Online]
Available at:
https://www.mla.com.au/contentassets/b6e72d8b5c52447d9f662fdc61124594/p.psh.0904_final_report.pdf
[Accessed 20 April 2022].

Matthewsmarking.com, n.d. *https://docs.matthewsmarking.com/ink-data-sheets/.* [Online]
Available at: https:/docs.matthewsmarking.com/ink-data-sheets/
[Accessed 20 April 2022].

Packingeurope.com, 2018. *https://packagingeurope.com/key-considerations-when-using-lasers-to-code-fruit-and-vegetables/5926.article.* [Online]
Available at: https://packagingeurope.com/key-considerations-when-using-lasers-to-code-fruit-and-vegetables/5926.article
[Accessed 20 April 2022].

Squires-shop.com, n.d. *https://www.squires-shop.com/product/sk-edible-glue-25g.* [Online]
Available at: https://www.squires-shop.com/product/sk-edible-glue-25g
[Accessed 20 April 2022].

9.0 Appendices

9.1 Appendix 1 – Countermark overview

9.1.1 Key Countermark characteristics

Countermark is a new type of data-carrier, it is similar to a QR code except Countermark uses two rows of human readable characters instead of black and white squares – giving important advantages:

- If the automated code reading fails the Countermark code can be entered manually
- Countermark can be printed by inkjet print printers which are already widely used in food processing
- Countermark is encrypted and has a private format so is very hard to falsify
- Each Countermark has data assigned after creation, so data from product processing, such as weight or end customer can be added after the Countermark has been printed
- The top row of a Countermark can be printed on delivery paperwork, linking the historical purchase records directly to a product and facilitating audits long after the food has been consumed.

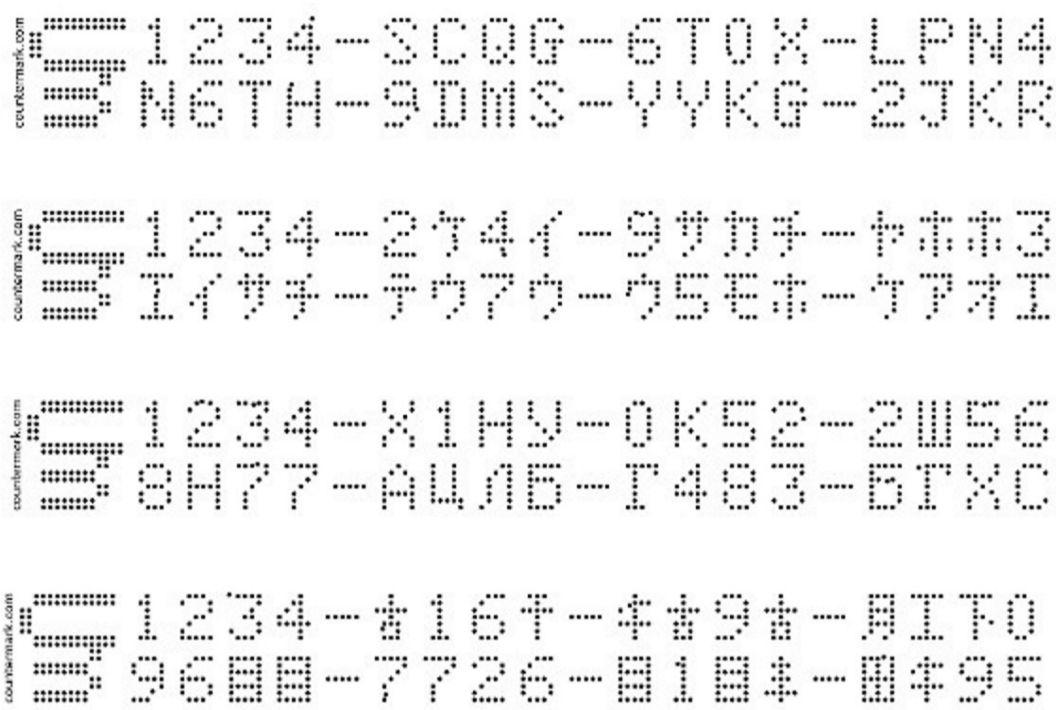


Figure 40 Countermark is available in Latin, Katakana, Cyrillic and Chinese fonts

9.1.2 Countermark as a digital signature

Countermark acts as a digital signature for the product it is printed on. Each Countermark:

- is unique and features randomised characters (eliminating sequential, predictable codes)
- acts like an encrypted hyperlink
- requires the Countermark app in order to access the data protected by the Countermark
- is backed by Blockchain to provide evidence of tampering.

9.1.3 Countermark fonts and manual data entry

Countermarks can currently be printed and read in four separate fonts, Latin, Katakana (Japan), Cyrillic (Eastern Europe), and Chinese (Figure 40). This allows human readability in most major economies. In all fonts the numbers 0-9 are used, with 22 alphabetic characters. This means that each block of 4 characters has 1,048,576 possible combinations. The encryption used in Countermark means individual symbols appear randomised.

The randomisation of the symbols means manual data entry of Countermarks is easier – the manual Countermark search software checks the internal Countermark record after each new symbol is entered. Entering just 4 symbols would find a unique Countermark within over a million possible combinations. This characteristic makes entering numbers manually much less onerous than conventional serial numbers.

9.1.4 Countermark spoof protection

The first four characters in the top row of a Countermark are known as “Top Left Text” and can be used for branding. In Figure 1 the “AMPC” refers to Australian Meat Processor Corporation. Countermarks used for Track 2 have 4MPC in this position to denote that the particular Countermark is part of this project, but operating on the development Countermark system. Fraud control systems operate in the Countermark software that detect if characters within the Top Left Text have been amended. If another Countermark user were to try to produce spoof Countermarks with AMPC in this position it would be detected the first time the Countermark was read and Wessex would know which account had created the fraudulent Countermark. This anti-spoof technology is simply not possible with public domain codes such as QR, Data Matrix or conventional bar codes.

9.1.5 Countermark uses dots

Countermark uses dots to form the basic element of a Countermark compared to black and white square cells of other codes. The use of dots gives two strong advantages to Countermark – dots are the basic element of inkjet print and laser marking which gives faster printing and better print results compared with trying to print solid blocks of ink with discrete dots as happens with other types of code. A second advantage is that the software algorithms used by Countermark do not need solid white backgrounds and solid black print to work. This allows Countermarks to be printed on and read from non-uniform surfaces.

9.1.6 Countermark top row as a public key

The top row of a Countermark can be used in a similar way to a public key in cryptography. The top row can be copied, shared and used to access the Countermark data system, however the Countermark top row cannot be used to generate an entire Countermark as would be present on a Countermark protected product. Adding Countermark to invoices, delivery notes etc. allows audits to be completed long after the product with the Countermark has been sold, or in the case of meat, eaten.

9.1.7 Countermark interfaces for printing and reading

Countermark has a range of print interfaces including Microsoft Windows, Comma Separated Value (CSV) files etc. Integrating Countermark with new printing devices is normally straight forward.

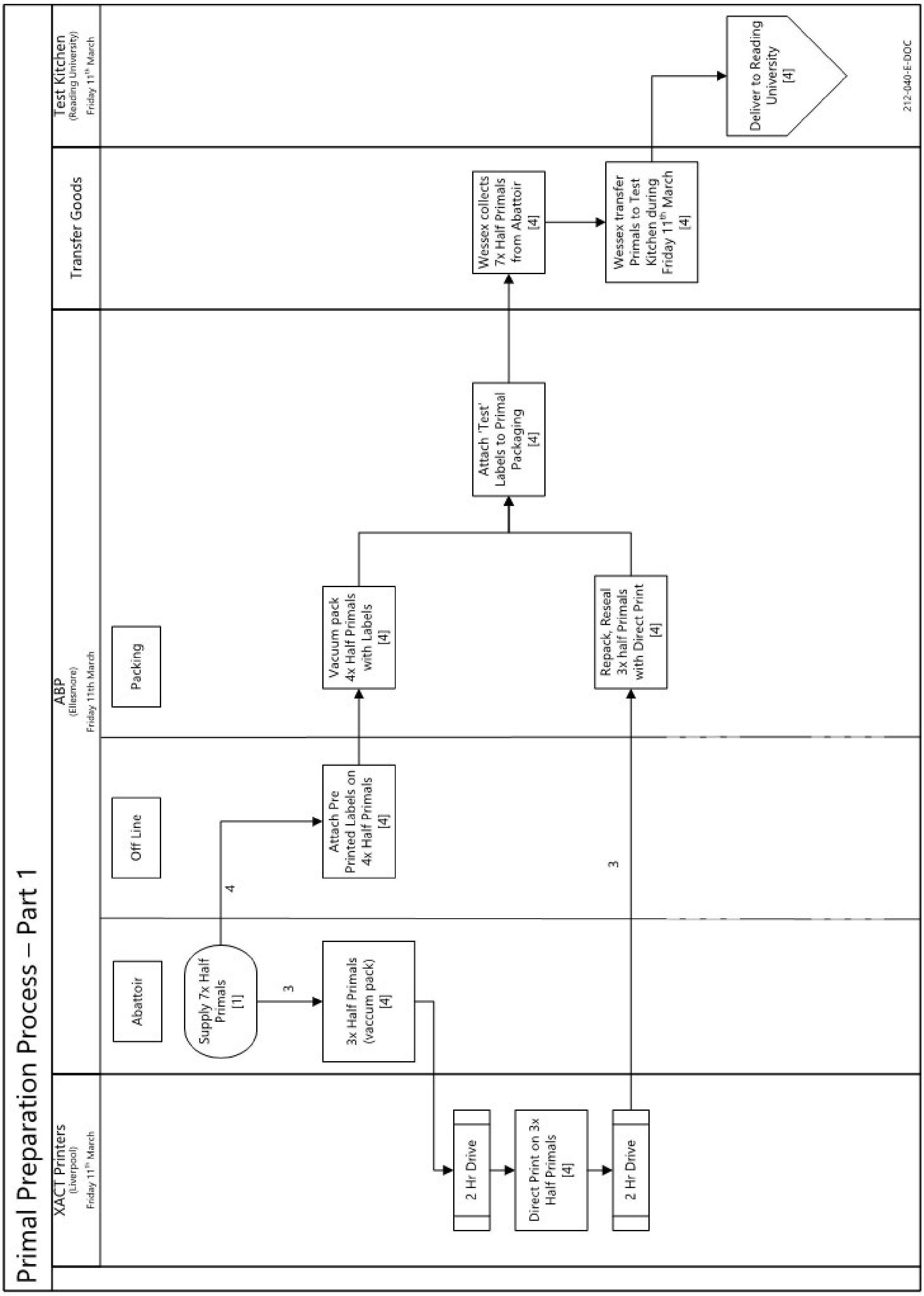
Countermarks can be read using the dedicated Countermark app for iPhone and Android. There are also API’s available to partner companies.

9.1.8 Further information

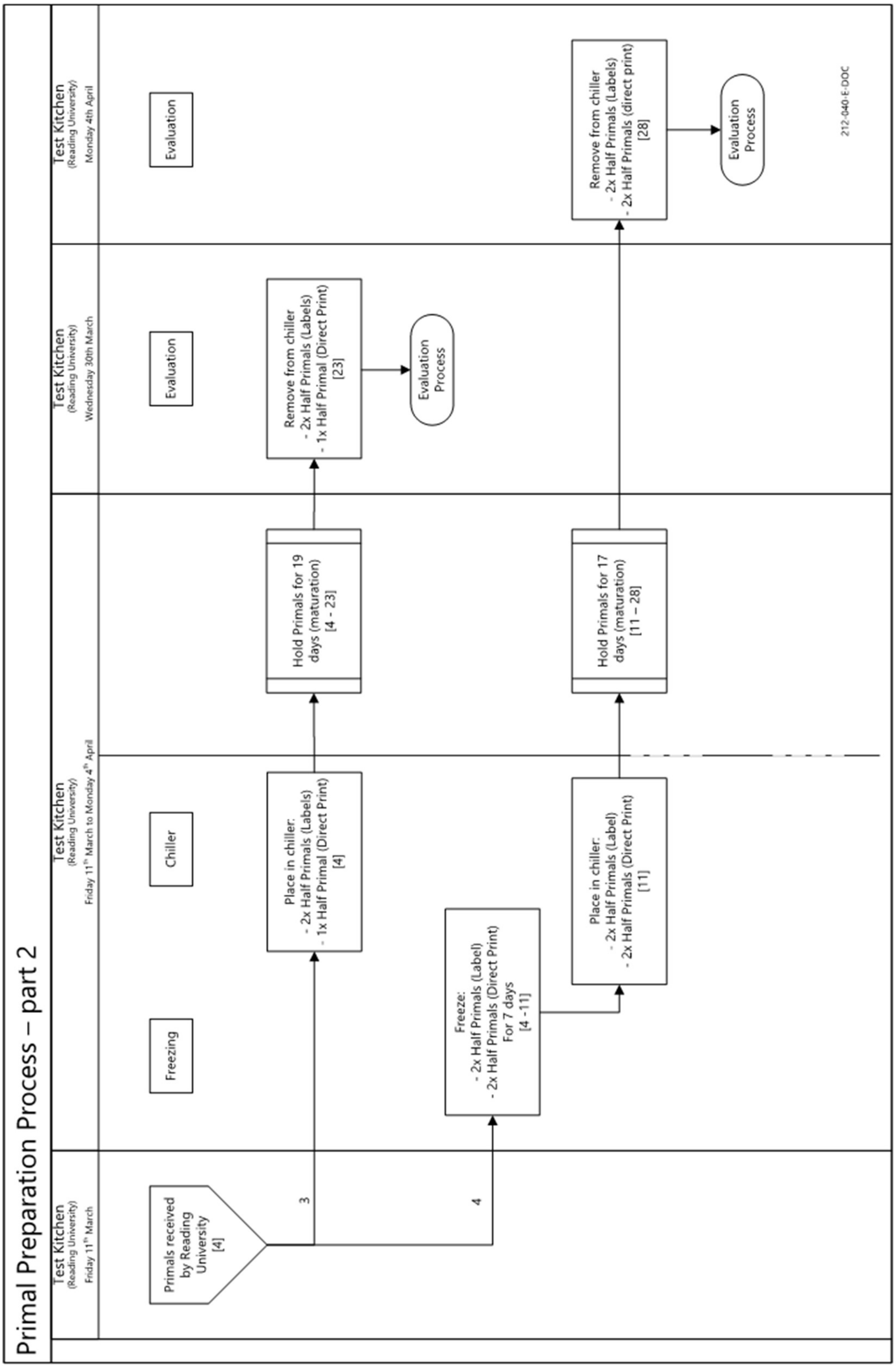
More information about Countermark can be found at www.Countermark.com

9.2 Appendix 2 – Primal thermal journey

Primal thermal journey – part 1 preparation



Primal thermal journey – part 2 journey simulation – freezing and maturation



9.3 Appendix 3 – Glossary

Term (From both reports)	Meaning
AMPC	Australian Meat Processor Corporation
Animal Identity	Nationally controlled system for identifying farm animals
Countermark	A proprietary printable data carrier developed by Wessex Technology OEP Ltd.
Cryovac	Proprietary shrink wrap plastic
CSV	Comma Separated Values – a file format used for data interchange between different software packages
Inkjet print, Inkjet printing	Older style of industrial printing where individual droplets of ink are ejected from a printing nozzle at high speed. Characters are formed from these individual dots, normally in a matrix of 7 dots high and 5 dots wide typically appearing as 1 2 3 A B C
n.d. (in bibliography)	No date
Track 1, Track 2	Sub-projects
Wessex	Wessex Technology OEP Ltd.