AMPC

FINAL REPORT

IMPROVED TRACEABILITY AND QUALITY CONTROL FOR MEAT PRODUCTS USING RFID

PROJECT CODE:	2020/1013
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DATE SUBMITTED:	30/10/2020
DATE PUBLISHED:	30/10/2020
PUBLISHED BY:	AMPC

The Australian Meat Processor Corporation acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

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1.0 EXECUTIVE SUMMARY

Through RAMP's experience, it has been identified that the UHF frequency band is sensitive to conductive materials, such as water and metal. Through various tests, it is known that the presence of a liquid in close proximity to an RFID tag will cause detuning of the RFID tag and prevent the RFID tag from activating in response to the UHF field.

The scope of this project was to investigate the feasibility of UHF RFID technology and its ability to detect meat products through attached RFID tags. This includes an in-depth study into the performance on RFID technology on different meat product SKU's and packing configurations.

This study involved the following:

- UHF RFID equipment testing using four sample cartons of meat provided by JBS Australia.

The steps taken by RAMP to conduct the study were as follows:

- Used UHF RFID technology to examine the RFID penetration characteristics on different meat product SKUs.
- Selected an appropriate UHF RFID Passive Tag for testing.
- Created a simulated production environment with which an RFID tunnel was used.
- Applied UHF RFID tags to all portions of meat within the sample cartons, and moved the cartons through the RFID tunnel to evaluate RFID read performance.

The results from the testing conducted have demonstrated that:

- Cartons that have been repacked in other configurations besides the *standard packing configuration* saw improved RFID read performance and reliability.
    - The *Navel Brisket* SKU had poor RFID performance with an average read rate of 68% in the *standard packed configuration* but saw the greatest improvements in the *outward packed configuration* with an average read rate of 100%.
    - The *Striploin* SKU had an average read rate of 100% across all five scenarios tests, but had improved read reliability in the *outward configuration* and *alternate tag orientation.*
    - The *Eye Round* SKU had considerable RFID performance with an average read rate of 90% in the *standard packed configuration.* The *outward configuration* provided the most considerable improvement with an average read rate of 100%.
    - The *Chuck Tender* SKU had considerable RFID performance with an average read rate of 96.44% in the *standard packed configuration.* The *outward configuration* and *alternate tag orientation* configurations improved performance, averaging at 100% tag read rates.

The recommendations from this study are:

- Modifying the existing packing configurations for improved RFID read performance across the four tested SKUs provided by JBS Australia.
- Modifying the remainder of the SKUs present at JBS Australia and verifying their performance through the RFID tunnel.
- Install an RFID tunnel at a JBS Meat Processing Facility and perform an extensive RFID pilot to examine performance within a production environment.

2.0 INTRODUCTION

JBS Australia is looking to use UHF RFID Passive Tags on meat products throughout the processing phase to identify the quantity and SKU of meat present in a given carton. UHF RFID technology has been proposed as a means of automating the verification process and eliminate sources of human error throughout the processing phase, particularly in relation to product identification and quantity checks.

JBS Australia has engaged with RAMP RFID to assess the validity of UHF RFID technologies to verify SKU carton during the manufacturing process.

3.0 PROJECT OBJECTIVES

UHF RFID often has exceptionally high read ranges in comparison to other frequencies used within RFID, and offer a good solution when tracking multiple items or assets when moving through defined spaces. Despite this, UHF frequencies are extremely susceptible to conductive materials and surfaces, such as metal and water, which can cause diminished performance.

The outcome of this project aims to evaluate the performance of UHF RFID antennas and RFID tags attached to meat products, with their potential application in providing real-time product identification and verification for use in downstream processes.

This study will achieve the following:

1. Identify and document the main requirements for RFID viability on meat products
    a. Identify geometric constraints (i.e. tag orientation, tag proximity, carton dimensions and space availability) that may impact RFID performance.
    b. Identify environmental constraints (i.e. temperature, humidity, conveyor speed, other processes) that may influence the simulated production environment used for testing.
2. Evaluating the performance of UHF RFID technologies.
    a. Testing of UHF RFID technology on JBS product samples in *standard packing configurations* for each carton in the RFID tunnel.
    b. Testing of UHF RFID technology on JBS product samples in an alternate packing configuration for each carton in the RFID tunnel to evaluate its performance against the *standard packed configuration*.
3. Outline results in relation to the UHF RFID performance
    a. Compare the performance of the *standard packed configuration* against an optimized packing configuration for the provided JBS product samples.
    b. Outline any process requirement changes that are necessary of JBS Australia to achieve statistically significate read rate performance for the provided JBS product samples.
4. Outline additional phases based on the recommendations of the study.

4.0 METHODOLOGY

4.1 Assumptions

There are a few assumptions that need to be considered to meet the objectives outlined by JBS Australia. These assumptions apply to all tests outlined in this document and are as follows:

- Cartons are fed into the system in the long-faced leading orientation.
- Unless otherwise specified, RFID label tags are placed where existing packaging labels are found on each product of each SKU.
- Time is measured when the carton enters and exits the RFID tunnel reader to determine the average conveyor speed of results.

4.2 Equipment

For this study, a test environment will be created to emulate the production environment of JBS Australia. In this environment, an RFID tunnel reader will be used alongside a moving platform. The moving platform will be placed on rails and will pass through the RFID tunnel reader to simulate a conveyor. Cartons will then pass through the RFID tunnel on the moving platform.

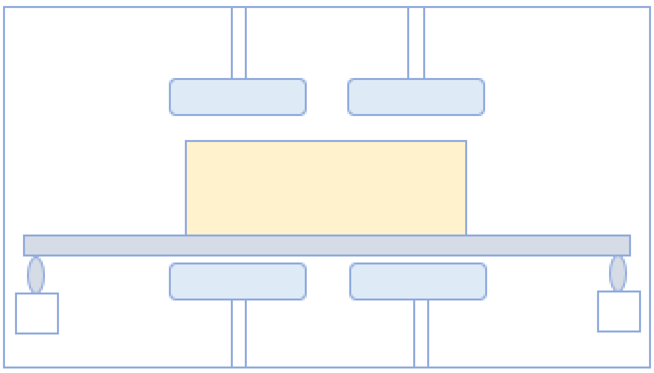

Figure 1. RFID tunnel configuration with the RFID antennas (blue), moving platform (grey) and the SKU carton (yellow)

The SKUs that will be tested in this study are:

- Navel Brisket – 2 units
- Striploin – 4 units
- Eye Rounds – 10 units
- Chuck Tenders – 9 units

Due to the nature of RFID, several factors must be considered prior to testing as it dictates the equipment used for the duration of the tests. These factors are outlined as follows:

- RFID Tag Variant
- RFID Antenna Placement
- RFID Reader Mode Settings
- RFID Power Level Settings

4.3 Preliminary Tests

4.3.1 RFID Tag Selection

Different RFID tags have different performance characteristics and are chosen to suit the intended use cases. This study aims at evaluating the performance of UHF RFID tags on meat products that are typically frozen, so the RFID tag should perform well in wet and cold environments as well as attenuation from being in close proximity to liquid bodies. As such, the candidate RFID tags for this are:

- 97mm x 27mm UHF RFID tag with Monza R6 chip*
- 97mm x 27mm UHF RFID tag with NXP UCODE8 chip

These RFID tags were applied to a SKU and moved through the RFID tunnel reader where a fixed UHF antenna will detect the applied tags. The read consistency of the RFID tags will provide an indicator on the performance of the RFID tag and will dictate the RFID tag used for the remaining tests.

Trial Number	Read Percentage	
	R6	UCode8
1	100%	76.04%
2	100%	88.69%
Total Average	**100%**	**82.37%**

Table 1. Average tag read percentage for 20 runs per trial of the Monza R6 chip and the UCode8 chip

Given the results in table 1, it can be seen that the Monza R6 RFID tag had consistent RFID read performance as opposed to the UCODE8 over 20 consecutive runs, and as such will be the chosen tag for the remaining tests.

*Note: The selected RFID inlay has been specifically modified so that it will be optimized for meats in a tunnel scanner environment.

4.3.2 RFID Antenna Placement

Since the heights of the cartons are fixed, the antennas above the platform will need to be taller than the carton to avoid clearance issues. This issue is not present for the RFID antennas located beneath the platform, and thus will be set as close as possible below the platform.

To test this, a carton will be placed in the RFID tunnel with two RFID antennas directly above the carton. The height will be adjusted in increments of 10mm away from the carton, with the tag readability measured for analysis. Given that the tallest carton is 212mm, our starting position will be 220mm from the platform and incremented until 320mm. This test will be tested against the "Medium" carton as this is the only carton size provided to RAMP RFID at the time of testing.

From our findings, the maximum height that we could move the RFID antennas was 250mm from the platform before there was performance degradation due to the distance. For the remaining tests, the RFID antennas will be set to 250mm, but it should be noted that RFID performance will vary for the smaller cartons used by JBS Australia due to the increased distance between the antenna and the carton. Additional testing will be required to confirm performance for the differently sized cartons.

4.3.3 RFID Reader Mode Settings

There are various settings that can be adjusted on the RFID reader modules to account for various situations. In this study, we'll to optimize the read settings for multiple RFID antennas and for densely packed meat. As such, the options that will be tested are:

- Max Throughput
- Max Miller
- Autoset Dense Reader Deep Scans
- Dense Reader – M8

Each SKU with tags applied will be passed through the tunnel for each setting, with the tag read rate recorded for analysis for all settings used. From our testing, each mode was able to consistently read the RFID tags, but *Max Throughput* provided the lowest RSSI values present so this setting will be applied throughout the remaining tests.

4.3.4 RFID Power Level Settings

To test the required power level settings, a margin test will be applied with a fixed UHF antenna and a carton located directly underneath. The test will involve cycling through various power settings and the tag read rate will be recorded, with the relevant RSSI values recorded for analysis.

In our findings, we've found that the highest power setting of 32.5 was required to consistently read the RFID tags applied to the meat, with lower power settings resulting in reduced tag readability with inconsistent read rates between test runs. Therefore, the power setting of 32.5 will be used for the remaining tests.

4.4 Test One – Packed as Received

This test is aimed at recording the tag read performance for the four given SKUs in the packing configuration as received from JBS Australia. The results of the test will highlight the performance of the RFID tags if used in place of the existing package labels.

For this test, each unit of each SKU will have an RFID tag applied to the meat where the existing label is, as shown in figure 2. Each SKU will be denoted by a letter followed by a number to assist in distinguishing between different SKU's and units when performing the test. For the provided samples, the SKUs will be labelled as follows:

- A – Navel Brisket
- B – Striploin
- C – Eye Round
- D – Chuck Tender

Each SKU will be packed in their respective carton in the standard packing configuration provided by JBS Australia. The carton will then be placed on the platform which is then passed through the RFID tunnel fifty times for accuracy. This process is repeated for all four SKUs provided, with the tag read performance and RSSI values recorded for analysis.

Refer to Appendix A for packing configurations for each SKU.

4.5 Test Two – Randomly Packed

This test is aimed at recording the tag read performance for each SKU in a randomly packed configuration, dissimilar to how it was received by JBS Australia. The results of the test will highlight the performance of the RFID tags, regardless of packing configuration.

For this test, each unit of each SKU will have an RFID tag applied to the meat where the existing label is, as shown in figure 2. Each SKU will be denoted by a letter followed by a number to assist in distinguishing between different SKU's and units when performing the test. For the provided samples, the SKUs will be labelled as follows:

- A – Navel Brisket
- B – Striploin
- C – Eye Round
- D – Chuck Tender

Each SKU will be randomly packed in their respective carton such that it does not match the configuration used by JBS Australia. The carton will then be placed on the platform which is then passed through the RFID tunnel fifty times for accuracy. This process is repeated for all four SKUs provided, with the tag read performance and RSSI values recorded for analysis.

Refer to Appendix A for packing configurations for each SKU.

4.6 Test Three – Foreign SKU

This test is aimed at recording the tag read performance for each SKU with a foreign SKU added to the standard packing configuration. The results of the test will highlight the performance of the RFID tunnel and its ability to detect additional foreign SKUs that are added to a carton.

For this test, each unit of each SKU will have an RFID tag applied to the meat where the existing label is, as shown in figure 2. Each SKU will be denoted by a letter followed by a number to assist in distinguishing between different SKU's and units when performing the test. For the provided samples, the SKUs will be labelled as follows:

- A – Navel Brisket
- B – Striploin
- C – Eye Round
- D – Chuck Tender
- F – Foreign SKU

Each SKU will be packed in their respective carton in the standard packing configuration provided by JBS Australia, with an additional foreign SKU added randomly to the carton. The carton will then be placed on the platform which is then passed through the RFID tunnel fifty times for accuracy. This process is repeated for all four SKUs provided, with the tag read performance and RSSI values recorded for analysis.

Refer to Appendix A for packing configurations for each SKU and location of foreign SKU.

4.7 Outward Configuration

This test is aimed at recording the tag read performance for each SKU in a configuration such that the RFID tag on each unit is facing outwards towards the closest wall of the carton. The results of the test will highlight the improved performance of the RFID tag when the RFID field is not directly impeded by the surrounding meat.

For this test, each unit of each SKU will have an RFID tag applied to the meat where the existing label is, as shown in figure 2. Each SKU will be denoted by a letter followed by a number to assist in distinguishing between different SKU's and units when performing the test. For the provided samples, the SKUs will be labelled as follows:

- A – Navel Brisket
- B – Striploin
- C – Eye Round
- D – Chuck Tender

Each SKU will be packed in their respective carton, with the RFID tag on the first layer facing down, and the RFID tags on the second layer facing up. The carton will then be placed on the platform which is then passed through the RFID tunnel fifty times for accuracy. This process is repeated for all four SKUs provided, with the tag read performance and RSSI values recorded for analysis.

Refer to Appendix A for packing configurations for each SKU.

4.8 Alternate Tag Orientation

This test is aimed at recording the tag read performance for each SKU with the tags moved and attached to the unit off center. Doing so will decrease the possibility of tag-on-tag interaction which would cause detuning and reduced RFID performance. The results of the test will highlight the performance of the RFID tag with a different tag orientation.

For this test, each unit of each SKU will have an RFID tag applied to the meat where the existing label is, as shown in figure 2. Each SKU will be denoted by a letter followed by a number to assist in distinguishing between different SKU's and units when performing the test. For the provided samples, the SKUs will be labelled as follows:

- A – Navel Brisket
- B – Striploin
- C – Eye Round
- D – Chuck Tender

Each SKU will be packed in their respective carton in the standard packing configuration provided by JBS Australia. The carton will then be placed on the platform which is then passed through the RFID tunnel fifty times for accuracy. This process is repeated for all four SKUs provided, with the tag read performance and RSSI values recorded for analysis.

Refer to Appendix A for packing configurations for each SKU.

5.0 PROJECT OUTCOMES

5.1 Test One - Packed as Received

Navel Brisket – Packed as Received

For the location reference of the first layer which includes RFID tag **A2,** refer to figure 3 in Appendix A.

For the location reference of the second layer which includes tag **A1,** refer to figure 4 in Appendix A.

	RFID Tag Number	
	A1	**A2**
Average RSSI	-60.45896739	-63.5587963
Average Tag Read Rate	100%	36%
Average Platform Velocity	1.17 m/s	
Overall Tag Read Rate	**68%**	

Table 2. Tag read performance for the Navel Brisket SKU in the standard packing configuration

Striploin – Packed as Received

For the location reference of the first layer, which includes tag **B1, B2 B3** and **B4,** refer to figure 11 in Appendix A.

	RFID Tag Number			
	B1	**B2**	**B3**	**B4**
Average RSSI	-57.0246	-61.7719	-65.3041	-62.2226
Average Tag Read Rate	98%	100%	98%	100%
Average Platform Velocity	0.88 m/s			
Overall Tag Read Rate	**100%**			

Table 3. Tag read performance for the Striploin SKU in the standard packing configuration

Eye Round – Packed as Received

For the tag locations of the first layer, which includes tag **C6, C7, C8, C9 and C10,** refer to figure 18 in Appendix A.

For the tag locations of the second layer, which includes tag **C1, C2, C3, C4 and C5,** refer to figure 19 in Appendix A.

	RFID Tag Number									
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
Average RSSI	-60.256	-58.038	-63.199	-60.993	-61.970	-59.502	-62.166		-55.922	-57.277
Average Tag Read Rate	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
Average Platform Velocity	0.84 m/s									
Overall Tag Read Rate	**90.00%**									

Table 4. Tag read performance for the Eye Round SKU in the standard packing configuration

Chuck Tender – Packed as Received

For the tag locations of the first layer, which includes tag **D6, D7, D8 and D9,** refer to figure 28 in Appendix A.

For the tag locations of the second layer, which includes tag **D1, D2, D3, D4 and D5,** refer to figure 29 in Appendix A.

	RFID Tag Number								
	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**
Average RSSI	-62.371	-57.560	-61.116	-54.825	-59.109	-64.113	-57.210	-54.282	-55.098
Average Tag Read Rate	100%	100%	100%	100%	100%	70%	100%	98%	100%
Average Platform Velocity	0.99 m/s								
Overall Tag Read Rate	**96.44%**								

Table 5. Tag read performance for the Chuck Tender SKU in the standard packing configuration

5.2 Test Two - Randomly Packed

Navel Brisket – Randomly Packed

For the tag locations of the first layer, which includes tag **A2,** refer to figure 5 in Appendix A.

For the tag locations of the second layer, which includes tag **A1,** refer to figure 6 in Appendix A.

	RFID Tag Number	
	A1	**A2**
Average RSSI	-61.37059975	-62.48564826
Average Tag Read Rate	80%	100%
Average Platform Velocity	1.48 m/s	
Overall Tag Read Rate	**90%**	

Table 6. Tag read performance for the Navel Brisket SKU in a randomly packed configuration

Striploin – Randomly Packed

For the tag locations of the first layer, which includes tag **B3 and B4,** refer to figure 12 in Appendix A.

For the tag locations of the second layer, which includes tag **B1 and B2,** refer to figure 13 in Appendix A.

	RFID Tag Number			
	B1	**B2**	**B3**	**B4**
Average RSSI	-64.2872	-56.5081	-65.8126	-59.5056
Average Tag Read Rate	100%	100%	96%	100%
Average Platform Velocity	0.97 m/s			
Overall Tag Read Rate	**100%**			

Table 7. Tag read performance for the Striploin SKU in a randomly packed configuration

Eye Round – Randomly Packed

For the tag locations of the first layer, which includes tag **C6, C7, C8, C9 and C10,** refer to figure 20 in Appendix A.

For the tag locations of the second layer, which includes tag **C1, C2, C3, C4 and C5,** refer to figure 21 in Appendix A.

	RFID Tag Number									
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
Average RSSI	-58.528	-57.547	-61.276	-61.037	-62.974	-61.106	-65.669	-54.793	-61.936	-61.183
Average Tag Read Rate	100%	100%	100%	100%	100%	100%	100%	100%	74%	96%
Average Platform Velocity	0.90 m/s									
Overall Tag Read Rate	**97.00%**									

Table 8. Tag read performance for the Eye Round SKU in a randomly packed configuration

Chuck Tender – Randomly Packed

For the tag locations of the first layer, which includes tag **D6, D7, D8 and D9,** refer to figure 30 in Appendix A.

For the tag locations of the second layer, which includes tag **D1, D2, D3, D4 and D5,** refer to figure 31 in Appendix A.

	RFID Tag Number								
	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**
Average RSSI	-60.531	-58.103	-57.760	-56.218	-59.275	-60.102	-58.451	-54.760	-60.059
Average Tag Read Rate	94%	100%	100%	98%	100%	98%	98%	100%	98%
Average Platform Velocity	1.56 m/s								
Overall Tag Read Rate	**98.44%**								

Table 9. Tag read performance for the Chuck Tender SKU in a randomly packed configuration

5.3 Foreign SKU

Navel Brisket – Single Foreign SKU

For the tag locations of the foreign SKU, which includes tag **F1,** refer to figure 7 in Appendix A.

	RFID Tag Number	
	A1	**F1**
Average RSSI	-61.1520169	-57.56143187
Average Tag Read Rate	100%	100%
Average Platform Velocity	1.08 m/s	
Overall Tag Read Rate	**100%**	

Table 10. Tag read performance for the Navel Brisket SKU with a foreign SKU added

Navel Brisket – Two Foreign SKUs

For the tag locations of the foreign SKU, which includes tag **A1, F1 and F2,** refer to figure 8 in Appendix A.

	RFID Tag Number		
	A1	**F1**	**F2**
Average RSSI	-63.47753279	-59.63458565	-63.45738751
Average Tag Read Rate	100%	100%	100%
Average Platform Velocity		0.99 m/s	
Overall Tag Read Rate		**100%**	

Table 11. Tag read performance for the Navel Brisket SKU with two foreign SKUs added

Striploin – Foreign SKU

For the tag locations of the first layer, which includes tag **F1, B2, B3 and B4,** refer to figure 14 in Appendix A.

	RFID Tag Number			
	F1	**B2**	**B3**	**B4**
Average RSSI	-61.5472	-59.0515	-64.5754	-61.3086
Average Tag Read Rate	100%	100%	100%	100%
Average Platform Velocity	1.03 m/s			
Overall Tag Read Rate	**99.00%**			

Table 12. Tag read performance for the Striploin SKU with a foreign SKU added

Eye Round – Foreign SKU

For the tag locations of the first layer, which includes tag **C6, C7, C8, C9, C10 and F1,** refer to figure 22 in Appendix A.

For the tag locations of the second layer, which includes tag **C1, C2, C3, C4 and C5,** refer to figure 23 in Appendix A.

	RFID Tag Number										
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**F1**
Average RSSI	-61.437	-58.835	-62.018	-60.684	-60.200	-61.074	-57.471	-61.160	-60.580	-57.605	-63.616
Average Tag Read Rate	100%	100%	100%	100%	100%	96%	100%	48%	46%	100%	100%
Average Platform Velocity	1.00 m/s										
Overall Tag Read Rate	**89.00%**										

Table 13. Tag read performance for the Eye Round SKU with a foreign SKU added

<u>Chuck Tender – Foreign SKU</u>

For the tag locations of the first layer, which includes tag **D6, D7, D8, D9 and F1,** refer to figure 32 in Appendix A.

For the tag locations of the second layer, which includes tag **D1, D2, D3, D4 and D5,** refer to figure 33 in Appendix A.

	RFID Tag Number									
	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**F1**
Average RSSI	-62.873	-57.786	-58.591	-56.252	-59.403	-59.395	-56.200	-56.562	-56.709	-68.618
Average Tag Read Rate	100%	100%	100%	100%	100%	100%	100%	100%	100%	80%
Average Platform Velocity	0.90 m/s									
Overall Tag Read Rate	**98.00%**									

Table 14. Tag read performance for the Chuck Tender SKU with a foreign SKU added

5.4 Outward Configuration

Navel Brisket – Outward Configuration

For the tag locations of the first layer, which includes tag **A2,** refer to figure 9 in Appendix A.

For the tag locations of the second layer, which includes tag **A1,** refer to figure 10 in Appendix A.

	RFID Tag Number	
	A1	**A2**
Average RSSI	-60.75249349	-59.1476321
Average Tag Read Rate	100%	100%
Average Platform Velocity	1.10 m/s	
Overall Tag Read Rate	**100%**	

Table 15. Tag read performance for the Navel Brisket SKU with the RFID tag facing outwards

Striploin – Outward Configuration

For the tag locations of the first layer, which includes tag **B3 and B4,** refer to figure 15 in Appendix A.

For the tag locations of the second layer, which includes tag **B1 and B2,** refer to figure 16 in Appendix A.

	RFID Tag Number			
	B1	**B2**	**B3**	**B4**
Average RSSI	-59.1368	-57.5727	-58.2889	-58.9085
Average Tag Read Rate	100%	100%	100%	100%
Average Platform Velocity	1.03 m/s			
Overall Tag Read Rate	**100%**			

Table 16. Tag read performance for the Striploin SKU with the RFID tag facing outwards

Eye Round – Outward Configuration

For the tag locations of the first layer, which includes tag **C6, C7, C8, C9 and C10,** refer to figure 24 in Appendix A.

For the tag locations of the second layer, which includes tag **C1, C2, C3, C4 and C5,** refer to figure 25 in Appendix A.

	RFID Tag Number									
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
Average RSSI	-60.664	-58.919	-62.913	-61.460	-61.396	-52.975	-60.608	-63.200	-57.912	-60.293
Average Tag Read Rate	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Average Platform Velocity	0.87 m/s									
Overall Tag Read Rate	**100%**									

Table 17. Tag read performance for the Eye Round SKU with the RFID tag facing outwards

Chuck Tender – Outward Configuration

For the tag locations of the first layer, which includes tag **D6, D7, D8 and D9,** refer to figure 34 in Appendix A.

For the tag locations of the second layer, which includes tag **D1, D2, D3, D4 and D5,** refer to figure 35 in Appendix A.

	RFID Tag Number								
	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**
Average RSSI	-64.125	-56.687	-59.258	-56.289	-58.481	-58.365	-57.388	-58.012	-55.516
Average Tag Read Rate	100%	100%	100%	100%	100%	100%	100%	100%	100%
Average Platform Velocity	1.07 m/s								
Overall Tag Read Rate	**100%**								

Table 18. Tag read performance for the Chuck Tender SKU with the RFID tag facing outwards

5.5 Alternate Tag Orientation

Navel Brisket – Alternate Tag Orientation

	RFID Tag Number	
	A1	**A2**
Average RSSI	-59.57038337	-58.23647131
Average Tag Read Rate	100%	100%
Average Platform Velocity	1.51 m/s	
Overall Tag Read Rate	**100%**	

Table 19. Tag read performance for the Navel Brisket SKU with the RFID tag in a fixed location and orientation

Striploin – Alternate Tag Orientation

For the tag locations of the first layer, which includes tag **B3 and B4,** refer to figure 17 in Appendix A.

For the tag locations of the second layer, which includes tag **B1 and B2,** refer to figure 18 in Appendix A.

	RFID Tag Number			
	B1	**B2**	**B3**	**B4**
Average RSSI	-53.7729	-57.5070	-57.2372	-53.9365
Average Tag Read Rate	100%	100%	100%	100%
Average Platform Velocity	1.00 m/s			
Overall Tag Read Rate	**100%**			

Table 20. Tag read performance for the Striploin SKU with the RFID tag in a fixed location and orientation

Eye Round – Alternate Tag Orientation

For the tag locations of the first layer, which includes tag **C6, C7, C8, C9 and C10,** refer to figure 26 in Appendix A.

For the tag locations of the second layer, which includes tag **C1, C2, C3, C4 and C5,** refer to figure 27 in Appendix A.

	RFID Tag Number									
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
Average RSSI	-60.845	-63.626	-60.281	-60.738	-59.884	-59.056	-62.745	-63.250	-58.483	-61.407
Average Tag Read Rate	100%	98%	100%	100%	100%	96%	98%	4%	98%	96%
Average Platform Velocity	0.88 m/s									
Overall Tag Read Rate	**89.00%**									

Table 21. Tag read performance for the Eye Round SKU with the RFID tag in a fixed location and orientation

Chuck Tender – Alternate Tag Orientation

For the tag locations of the first layer, which includes tag **D6, D7, D8 and D9,** refer to figure 36 in Appendix A.

For the tag locations of the second layer, which includes tag **D1, D2, D3, D4 and D5,** refer to figure 37 in Appendix A.

	RFID Tag Number								
	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**
Average RSSI	-59.944	-52.744	-58.162	-52.776	-55.294	-55.235	-57.612	-54.389	-54.937
Average Tag Read Rate	100%	100%	100%	100%	100%	100%	100%	100%	100%
Average Platform Velocity	1.00 m/s								
Overall Tag Read Rate	**100%**								

Table 19. Tag read performance for the Chuck Tender SKU with the RFID tag in a fixed location and orientation

6.0 DISCUSSION

Navel Brisket

With the Navel Brisket SKU, we can see that the tag read performance is dependent on the position and configuration of the units within the carton. From the standard packed configuration, we can see that the performance is severely diminished, with the worst performing tag being read only 38% of the time as shown in table 2. This is caused by the position of the tag, as it is encased between both units of Navel Brisket which absorb the RFID field before it reaches the RFID tag.

This effect is alleviated most notably in *test 4* as both tags used are not impeded by the meat products as they're facing outwards. By doing so, they're able to function correctly within the RFID field which is reflected by the 100% average tag read rate shown in table 15.

The other tests performed on this SKU also reflect these improvements by modifying the configuration, with the results showing a 100% average tag read rate in all scenarios tested. In conclusion, we can state that the performance of RFID on the Navel Brisket SKU is hampered when using the standard packing configuration, but can be significantly improved by altering the configuration of the meat, or by moving the location of the label to a more ideal location.

Striploin

With the Striploin SKU, we can see that the tag read performance across all five scenarios was consistent and had an average tag read rate of 100%, even with foreign SKUs added to the carton as shown in table 11. Analyzing the RSSI values across these tests, we can see that the tags performed the best during the *Alternate Tag Orientation* scenario, followed by the *Outward Configuration* because the tags were positioned to face the RFID antennas and were not directly obscured by other units of meat. The standard packing configuration performed not as well in comparison to the other two scenarios but was still able to achieve a 100% read rate as the tags were only slightly obscured by the other units of meat, but was not sufficient enough to hamper performance.

Based on the results, it is recommended to have the meat oriented in the *Outward Configuration* or the *Alternate Tag Orientation* for consistent performance.

Eye Round

The Eye Round SKU had comparatively thicker portions of meat comparable to the Navel Brisket SKU and faced similar issues with the *Standard Packing Configuration* test. The tag read performance improves once the configuration is broken, as shown in table _ where the average tag read rate moves from 90% to 97% in the *Randomly Packed* test and 99% in the *Foreign SKU* test.

The *Alternate Tag Orientation* test also faced similar issues to the *Standard Packing Configuration* since that tags were still being encased by the meat, despite being moved to an alternate location. Overall, the only scenario that could produce consistent results was the *Outward Configuration* and is the recommended configuration for consistent performance.

Chuck Tender

The Chuck Tender SKU performed well across all five tests, with the lowest read rate being 96.44%. The SKU faces similar issues to the Eye Round SKU and Navel Brisket SKU in that the first layer of RFID tags is completely obstructed by the second layer of meat, but can still be detected since the layers are comparatively thinner.

In the *Foreign SKU Added* test, if we don't account for the foreign SKU then there is a 100% read rate for all intended items in the carton, with the foreign SKU only detected at an average rate of 80%. The lower performance for the foreign SKU can be attributed to the location of the SKU as the tag was significantly closer to the RFID antenna and may have been passing through a dead zone.

Overall, the SKU performed best during the *Outward Configuration* and *Alternate Tag Orientation* with an average tag read rate of 100% and significantly improved RSSI values compared to previous tests. Like the other SKUs, the improved performance is attributed to the lack of meat obstructing the RFID tag and causing detuning. Based on these results, it is recommended to have the Chuck Tender SKU in the *Outward Configuration* or *Alternate Tag Orientation* for consistent performance.

Other Considerations

There are many other factors associated with RFID that must be considered to ensure optimal performance of the RFID tags.

In all tests performed, it was ensured that no RFID tags were in direct contact with one another to prevent what is known as detuning. By doing so, the tags will be unable to receive the signal from the RFID antennas and will not respond accordingly. The *Alternate Tag Orientation* test aimed at moving the RFID tag into a location such that this was not possible, despite how the meat was packaged in their respective cartons. RAMP recommends that all configuration changes the JBS makes avoid having tag-on-tag interactions as it will severely hamper tag read performance overall.

The power level for the RFID tunnel was set to the maximum and may cause unintended reads for tags outside of the RFID tunnel which could skew the results in a production environment. In our testing, we've found that an exclusion zone is required at the entrance and exit of the tunnel to prevent unintended reads of adjacent cartons. The size of this exclusion zone is approximately 500mm outwards from the entry and exit points for all SKUs tested.

As a result of the power level being set to maximum, it is highly likely that the RFID tunnel will be able to detect tags that have not been applied onto the meat products as they're more easily detected in open air. Therefore, the power setting may need adjustments depending on where it is setup to prevent unintentional reads of tags within the area.

7.0 CONCLUSIONS/RECOMMENDATIONS

The key conclusions from RAMP's testing are:

- The *Standard Packing Configuration* produced sub-optimal results, with some SKUs being detected more easily than others.
- The *Outward Configuration* produced the best and most consistent results out of all five tested scenarios, averaging 100% tag read rate.
- The *Alternate Tag Orientation* produced improved results but not to the same degree as the *Outward Configuration*.
- The RFID tunnel is able to detect foreign SKUs at an average accuracy of 96.5% of the time across all SKUs provided by JBS Australia. This number is only indicative of performance for the SKUs tested, and further testing would be required for optimization and improvements.
- Further testing is required to test the suitability of the RFID tunnel for all of JBS Australia's SKUs and their different carton sizes.

RAMP recommends the next steps following this study:

- Packing configuration changes will be required for optimal performance for use with the RFID tunnel, with RAMP recommending the *Outward Configuration* to achieve this.
- Install an RFID tunnel at a JBS facility and conduct onsite testing for all SKUs produced by JBS Australia.

8.0 APPENDICES

8.1 Appendix A

Navel Brisket – Test One – Packed as Received

Figure 3. First layer of Navel Brisket SKU for the Standard Packed Configuration

Figure 4. Second layer of Navel Brisket SKU for the Standard Packed Configuration

Navel Brisket – Test Two – Randomly Packed

Figure 5. First layer of Navel Brisket SKU for the Randomly Packed Configuration

Figure 6. Second layer of Navel Brisket SKU for the Randomly Packed Configuration

Navel Brisket – Test 3 – Foreign SKU

Figure 7. Navel Brisket SKU with a single foreign SKU added

Figure 8. Navel Brisket SKU with two foreign SKUs added

Navel Brisket – Test 4 – Outward Configuration

Figure 9. First layer of Navel Brisket SKU for the Outward Configuration

Figure 10. Second layer of Navel Brisket SKU for the Outward Configuration

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Striploin – Test One – Packed as Received

figure 11. First layer of Striploin SKU for the Standard Packed Configuration

Striploin – Test Two – Randomly Packed

Figure 12. First layer of Striploin SKU for the Randomly Packed Configuration

Figure 13. Second layer of Striploin SKU for the Randomly Packed Configuration

Striploin – Test 3 – Foreign SKU

Figure 14. Striploin SKU with single foreign SKU added

Striploin – Test 4 – Outward Configuration

Figure 15. First layer of Striploin SKU for the Outward Configuration

Figure 16. Second layer of Striploin SKU for the Outward Configuration

Striploin – Test 5 – Alternate Tag Orientation

Figure 17. First layer of Striploin SKU for the Alternate Tag Orientation

Eye Round – Test One – Packed as Received

Figure 18. First layer of Eye Round SKU for the Standard Packed Configuration

Figure 19. Second layer of Eye Round SKU for the Standard Packed Configuration

Eye Round – Test Two – Randomly Packed

Figure 20. First layer of Eye Round SKU for the Randomly Packed Configuration

Figure 21. Second layer of Eye Round SKU for the Randomly Packed Configuration

Eye Round – Test 3 – Foreign SKU

Figure 22. First layer of Eye Round SKU with a single foreign SKU added

Figure 23. Second layer of Eye Round SKU with a single foreign SKU added

Eye Round – Test 4 – Outward Configuration

Figure 24. First layer of Eye Round SKU for the Outward Configuration

Figure 25. Second layer of Eye Round SKU for the Outward Configuration

Eye Round – Test 5 – Alternate Tag Orientation

Figure 26. First layer of Eye Round SKU for the Alternate Tag Orientation

Figure 27. Second layer of Eye Round SKU for the Alternate Tag Orientation

Chuck Tender – Test One – Packed as Received

Figure 28. First layer of Chuck Tender SKU for the Standard Packed Configuration

Figure 29. Second layer of Chuck Tender SKU for the Standard Packed Configuration

Chuck Tender – Test Two – Randomly Packed

Figure 30. First layer of Chuck Tender SKU for the Randomly Packed Configuration

Figure 31. Second layer of Chuck Tender SKU for the Randomly Packed Configuration

Chuck Tender – Test 3 – Foreign SKU

Figure 32. First layer of Chuck Tender SKU with a single foreign SKU added

Figure 33. Second layer of Chuck Tender SKU with a single foreign SKU added

Chuck Tender – Test 4 – Outward Configuration

Figure 34. First layer of Chuck Tender SKU for the Outward Configuration

Figure 35. Second layer of Chuck Tender SKU for the Outward Configuration

Chuck Tender – Test 5 – Alternate Tag Orientation

Figure 36. First layer of Chuck Tender SKU for the Alternate Tag Orientation

Figure 37. Second layer of Chuck Tender SKU for the Alternate Tag Orientation