Final report

Visual indicators to monitor shelf life in Australian retail supply chains

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Abstract

The assignment of product shelf life is often arbitrary and is based on ideal or specified storage temperatures which may not be met in practice. The Keep-It technology is a visual shelf-life forecasting technology that gives a more accurate assessment of expiry than subjective shelf life labelling. The temperature-responsive nature of the visual label allows consumers the flexibility of proper planning, and retailers to better manage their chilled categories via implementing proper storage and quality assurance (QA) decisions. Laboratory shelf life tests on Darfresh-packed Australian beef were conducted and Keep-It indicators were found to slightly underestimates the shelf-life at low temperatures (2 °C) and overestimate the shelf-life at higher temperatures (6.6 °C) when compared to the UTas/MLA shelf life calculator. Preliminary testing in store demonstrated that the Keep-It indicators could detect suboptimal storage conditions, which were able to be corrected via prompt QA action not achievable with other technologies. Collecting data from the indicators was easier, faster, and more reliable than collecting the data from temperature data loggers. A survey of consumers in stores indicated that adequate education of the technology was needed prior to a release to the general public. Without the education, benefits were limited to the logistics and retail supply chain participants, and not fully utilised by the consumer. The Keep-It technology offers an opportunity for red meat retail supply chains to ensure that consumers are provided with easily understood shelf life data that will help them make informed consumer purchasing decisions and better assist the retailer with their QA decision making. The Keep-It technology is currently under review from European food authorities with regard to legislation of their date stamping protocols. Once fully assessed, the Keep-It technology will be a major part of European retail supply chains. This includes, but is not limited to, red meat, seafood and fresh fruit and vegetables.

Executive summary

Background

The determination of shelf-life is often arbitrary and is based on ideal or specified storage temperatures which may not be met in practice. While predictive models for shelf-life are available they are usually applied retrospectively or do not inform customers on the potential shelf-life for products they are purchasing. A visual shelf-life indicator such as the Keep-It Indicator may offer savings to the retailer as well as provide confidence to consumers, if it accurately reflects shelf-life remaining under expected storage conditions.

MLA has developed protocols for shelf life determination, and, with University of Tasmania, developed a model that will predict the shelf life of vacuum packed beef and lamb. The use of the model to develop good cold chain management is estimated to be able to save the industry over $100m per annum in product wastage (V.MFS.0447). Good cold chain management, developed with data loggers, fails to provide a carton or package-level assurance of shelf life to consumers.

The research undertaken within this report has been completed with the objective of informing retailers, suppliers and consumers in a red meat supply chain about the Keep-It technology and the application it can have within industry. The milestones of the report included verification of the technology together with a comparison to the MLA/UTas model. Once the verification was completed there was a quantitative and qualitative analysis of the cost and benefit to the Australian red meat industry. The main demographic and target audience for the report is consumers who intend to purchase sustainable and quality-based products, alongside of the retailers who are bringing red meat items to the Australian market.

Objectives

1. Verify that Keep-It indicators accurately reflect the shelf life of products held at various temperatures within the laboratory
2. Determine the effective shelf life in a selected supply chain, through temperature monitoring and application of the University of Tasmania shelf life model for VP and Darfresh from processing to retail
3. Demonstrate the Keep-It indicator system in an Australian processor to retail and consumer supply chain and measure the response of the supply chain/consumer.
4. Determine how Australian consumers would respond to a Keep-It indicator across a range of fresh meat products

Methodology

Laboratory shelf life tests to verify Keep-It indicator performance was followed by supervised retail trials in which packed product was followed from the central packing room to several retail stores and the behaviour of the indicators and how they could be used within the retail environment was explored. In-store interviews were conducted with potential consumers to understand their response to a Keep-It indicator.

Results/key findings

Keep-It indicators were found to underestimates the shelf-life at low temperatures (2 °C) and overestimate the shelf-life at higher temperatures (6.6 °C) when compared to the UTAS/MLA shelf

life calculator. Preliminary testing in store demonstrated that the Keep-It indicators could detect suboptimal storage conditions, which were able to be corrected. A survey of consumers in stores indicated that 79% of consumers felt secure that the food they buy with a Keep-It indicator applied is higher quality than those meat brands without the assurance. Of all questions asked, the instances of a positive response was 67%, with the remaining being 13% neutral and 20% negatively responding to the technology. The major focus from consumers in the study was broken into two categories of people. Consumers who had a higher perception of the importance for Product integrity and Sustainability benefits were consistently positive and considered the key demographic that this technology can be delivered to.

Benefits to industry

The Keep-It technology offers an opportunity for red meat retail supply chains to ensure that consumers are provided with easily understood shelf life data that will help them make informed purchasing decisions. An informed client is more likely to be satisfied with the decision and return to the same retail outlet for their future purchases. For retailers who have an informed client base, the gross benefits can simplify to additional customers, increased sales per customer and waste reduction – all resulting from the implementation of technology. The ability to rapidly identify supply chain inefficiencies or disruptions using the Keep-It are far more advanced than other management tools in the market today. The technology is also simple to use so that all participants can take decisive action.

Future research and recommendations

Based on the results of the project and associated research, the waste component of a retailer business and the related consumer waste component was likely to exceed UN estimates[1]. Regardless of implementation of the Keep-It technology, the red meat supply chain can be improved upon. Retailers are doing a decent job at keeping waste and mark-down figures low, however this is based on company KPIs and financial decision making. There are other technologies available to lower waste and mark-down figures such as fading sensor technology, or touch sensitive technology but each of these struggle to compete with the simple and effective forecasting nature of Keep-It technology.

The opportunity cost to a retail business for not pushing clients to potentially buy more and taking a "waste risk" is unknown. Consumers are willing to trust the technology employed and the retail entity which they buy from. Having a greater knowledge of the supply chain has shown that consumers are willing to consume near-date expiry products as long as they are able to confirm it is safe. It is recommended that retailers utilise the Keep-It technology and in doing so, create a higher engagement with consumers. This will result in a lower waste and mark-down profile while also increasing basket size and consumer loyalty to their brand.

[1] Appendix reference 8.1.1

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1. Background

The determination of shelf-life is often arbitrary and is based on ideal or specified storage temperatures which may not be met in practice. While predictive models for shelf-life are available they are usually applied retrospectively or do not inform customers on the potential shelf-life for products they are purchasing. A visual shelf-life indicator such as the Keep-It Indicator may offer savings to the retailer as well as provide confidence to consumers, if it accurately reflects shelf-life remaining under expected storage conditions.

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The Keep-It Indicators are a visual representation of the days remaining of a perishable food item according to the relative temperature the product has been stored since production (refer to **Figure 1**, noting the image can be read similar to reading the battery remaining on a smart phone). The technology works as a function of temperature and time, with the predicted shelf life of unique products mapped according to a starting microbial point and the relative change when subjected to different environmental temperatures.

Figure 1 – Keep-It Indicator showing less than 14 days until expiry.

Temperature Data Loggers are available for use within Australian industry standards. This is a key measure for the study being relevant in today's red meat supply chain. Demonstrating this technology in conjunction with the Keep-It technology will allow a full assessment of the application within industry.

2. Objectives

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4. Determine how Australian consumers would respond to a Keep-It indicator across a range of fresh meat products

3. Methodology

3.1 Laboratory validation

3.1.1 Design of the study

Three sets of 12 samples were supposed to be stored at 2, 4 and 8 °C, while one set of 12 samples was shifted between 4 and 8 °C every 48 hours to mimic temperature fluctuations during storage. *Unfortunately, failures at the testing laboratory resulted in samples being stored at 2, 6.6 and 2 to 6.6 °C.* Samples were stored in incubators in stacks of three. Sampling times were selected considering the recommendations outlined in the MLA publication 'Shelf-life of Australian red meat, 2nd edition'[2], with sample times clustered around the expected shelf-life as predicted by the UTas model.

3.1.2 Sample analysis

Triplicate samples were removed from storage at specific times as determined by the storage temperature. On removal the samples were photographed to capture the Keep-It indicator reading. A ruler was placed beside the keep-It indicator to allow for a more repeatable estimation of the shelf-life remaining as indicated by the Keep-It technology (Figure 1). Samples were assessed for appearance and then opened and assessed for off-odours. Sample analysis was completed within 30 minutes of removal from the incubator. Results for colour and appearance were reported as satisfactory or unsatisfactory.

Following organoleptic assessment samples were analysed for aerobic plate count following the protocol outlined in AS 5013.5. Counts were $\log_{10}$ transformed and the average of the three results reported as the Log_{10} CFU/g

3.1.3 Predicting the remaining shelf life

The shelf-life remaining was estimated using the UTas model with an assumed starting count of 400 CFU/g (the approximate starting count as determined by sampling in the laboratory). The preferred storage temperature in the model was set to the average storage temperature (2.1 °C and 6.6 °C, respectively) to obtain more meaningful shelf-life results. For the product switched between 2 and 7

[2] Section 9.2 https://www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/food-safety/pdfs/shelf-life-of-australian-red-meat-2nd-edition.pdf

°C a preferred temperature of 4.2 °C was used. The model was run until the shelf-life remaining reached zero.

3.2 Retail supply chain

To determine the comparative effect within an open supply chain, Temperature Data Loggers were input to trial supply chain at the point of load out from the manufacturing facility. The data loggers were removed from the supply chain at the discretion of store managers, once arriving at the destination of product display to consumers. This gave an accurate representation of real and existing supply chain practices. The actual temperature data derived from the loggers was irrelevant for this methodology, due to the objective of obtaining adequate information for managers to make an informed decision on supply chain events.

The initial assumption was made that both Temperature Data Loggers and Keep-It Indicators were used in a temperature compromised supply chain in order to prompt the quick return of the Data Logger for analysis by the management receiving the goods.

Because no management of the data for Keep-It Indicators was necessary, project staff were only instructed to take images on a regular basis, with the preference being twice daily.

To correctly assess the level of acceptance and therefore benefit, a numerical value was assigned to each of the possible outcomes “Acceptable”, “Marginal” and “Unacceptable”. This is identified below in **Error! Reference source not found.** and further expanded upon in section **Error! Reference source not found.**1 and section **Error! Reference source not found.**.2 of this report.

Table 1 – values assigned to acceptance levels for data analysis.

	Acceptance value	**Notation**
Acceptable	2	*Provides a benefit to the red meat industry above other options available*
Marginal	1	*Provides a benefit to the red meat industry as good as other options available*
Unacceptable	0	*Provides no benefit to the red meat industry*
Total achievable across categories	8	

3.2.1 Design of the study

When comparing the Keep-It technology to existing quality measurement tools (UTas model coupled with data-loggers), there are two components to assess. The speed of information transfer is critical in today’s supply chain in order to identify and amend supply chain issues. The second is having the necessary data points to make informed decisions. It was determined that the Keep-It Indicators were best for creating a complete view of the retailer’s supply chain that is actionable for the critical participants in a prompt manner. Results were split into these categories for ease of analysis.

Category 1: Analysis of the ability to rapidly identify supply chain issues.

Category 2: Analysis of Waste and Waste reduction considerations, leading to the optimised shelf life of products.

3.2.2 Samples

- Darfresh products were packaged at an export meat processing facility and Keep-It indicators applied to the outside of the individual packs.
- Temperature Data Loggers were put into various cartons of each delivery. The timing of putting data loggers into the loadout cartons was determined by normal facility practices.
- Normal food safety practices[3] were expected.
- Data samples recorded were:
    - Volume of data points.
    - Days of data available (displayed as a percentage of the product's total shelf life).
    - Speed of data transfer.
    - Time of day data was received.

3.2.3 Sample collection

- Temperature Data Loggers[4] were retrieved from cartons at the discretion of store managers.
- Data was downloaded as soon as QA managers received the loggers and the time logged.
- The data for Keep-It Indicators was collected at various intervals for the entire time products were on shelves. Products were not monitored once they left the store.
- The time stamp of images (containing information of the Keep-It Indicators) was automatically recorded by sending the images to the project manager via WhatsApp at the time of collection.
- Retail fridge unit's temperature screens were recorded at the same time Keep-It indicator records taken where visible and available.

3.2.4 Data collection

- Triplicate data from the Temperature Data Loggers was assessed against the UTAS model. Literature for the model can be found within the MLA publication 'Shelf-life of Australian red meat, 2nd edition'[5].
    - Sample data from the data loggers was extrapolated out until the dates of Keep-It Indicator analysis to make the data readings more assessable, however only real data was considered as accurate and therefore assigned an acceptance level according to this.
- Each of the Keep-It Indicator readings were compared to the information retrieved from the period of valid data for each logger to identify and exclude any potential outliers.
- Results of the volume of data were reported as Acceptable, Marginal and Unacceptable according to the two categories.
- Results of the days of data available were recorded as a percentage of the pre-determined shelf life of different products.
- Results of the speed which raw data was available was recorded.

[3] https://www.legislation.gov.au/Series/F2008B00576
[4] TempTale Ultra Fit brand; CE, RTCA – D016ØG compliant, RoHS compliant, Response time tested to U.S. Pharmacopeia (USP) and EN 12830 standards
[5] Section 9.2 https://www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/food-safety/pdfs/shelf-life-of-australian-red-meat-2nd-edition.pdf

- Results of the speed of data transfer to the project manager were reported as Acceptable, Marginal and Unacceptable according to the two categories.

3.2.5 Comparing the data obtained

For both objective categories, speed of information transfer was the underlying principle to define benefits to the Australian red meat supply chain. Time frame between receiving data to analysing it, the accuracy of information, and the span of time which data was available within the supply chain were categorised as Acceptable, Marginal and Unacceptable. Having prompt information which is actionable

3.3 Retail consumers

3.3.1 Design of the study

The requirement to have a diverse study population was met through selecting various retail locations, at various times of the day and each day of the week. Respondents needed to be actively looking for a meat product within the correct section of the retail store before being approached for the survey. Validation questions[6] were asked to map the distribution of age, sex and knowledge of the Keep-It technology. Those respondents who had limited or no knowledge of the technology were given an explanation and asked if they felt comfortable to proceed on that basis.

The most simplistic way to explain the technology to a consumer was by stating "The Keep-It Indicators are a visual representation of the days remaining of a perishable food item (and comparing reading the expiry of a package in store to reading the battery remaining on a smart phone)".

Because all respondents were either aware of, or made aware of the technology, it was possible to assign an acceptance value to each question as "positive", "neutral" or "negative". This is identified below in Table 2 and further expanded upon in section 3.3.3 and section 4.3 of this report.

Table 2 – values assigned to acceptance levels for data analysis.

	Acceptance value	Notation
Positive	2	*Provides a benefit to the consumer above other options available from the retailer and red meat suppliers.*
Neutral	1	*Neutral impact on the consumer's interaction with the retailer and red meat industry*
Negative	0	*Provides no benefit to the consumer in making purchasing decisions*

Consumers were informed that the survey was independent of the retailer, and that the results would be shared amongst industry. The first four questions were asked, at which point a go-no-go decision was made. If the respondent had not previously seen or bought fresh food with the Keep-It indicator present, they were given an opportunity to walk away from the survey, or to get a quick introduction[7] and proceed as explained in sections 3.3.2 and 3.3.3. Those respondents who did not want to participate past question four of the survey were noted and excluded from the results.

[6] Appendix 8.3
[7] Introduction to Keep-It technologies (a one pager)- Appendix 8.2.1

3.3.2 Sample analysis

Some respondents gave multiple answers to a question. In this case, if the answers were on the same side of the acceptance scale they were included as the more neutral option. In the case where two answers were of opposite logic, the results of that question were excluded from the study. If multiple answers from one respondent had opposing logic, the whole dataset from that person was considered unacceptable and excluded.

Results were also split into a category of focus - the options being sustainability, economic or a mixture of both. This data was analysed for any trends between the categories of macro acceptance; sustainability, and economic focus. Presenting the split analysis was unnecessary for the final report due to the high correlation between economic benefit and environmental benefit (sustainability).

3.3.3 Applying a quantitative measure to qualitative data

In assessing the responses to all questions with an association of Highly Positive, Positive, Neutral, Negative and Highly Negative we were able to create a quantitative representation of the qualitative dataset. A sum of all instances (responses) was compiled, and a percentage derived from this as seen in Table 3.

Table 1 - Applying quantitative values to qualitative data

Acceptance Value	instances (question basis)	percent of instance
Highly Positive	8	17.78%
Positive	11	24.44%
Neutral	9	20.00%
Negative	11	24.44%
Highly Negative	6	13.33%

4 Results

4.1 Verification of Keep-It indicators against product shelf life and UTAS shelf life calculator prediction

4.1.1 Microbiological and Organoleptic results

The aerobic plate count over time was typical for vacuum packaged product with the count increasing steadily until a final population of around 10^7 CFU/g was reached. This is a little lower than might be expected for vacuum packaged product but is probably the result of a tissue sample being analysed rather than a surface sample, which might be expected to be higher. No attempt was made to identify the dominant bacterial species present.

Organoleptic evaluation was limited to visual and olfactory assessment due to only one sampling occasion resulting in an organoleptically unsatisfactory result. Even though off flavours were not examined it is unlikely that such flavours would develop without associated off-odours. All samples evaluated in this study had a longer than expected organoleptic shelf-life.

4.1.2 Shelf-life of Darfresh products stored at various temperatures

Aerobic plate count and shelf-life remaining for product stored at 2.1, 6.6 and 2.1 - 6.6 °C are summarised in Figure 2 to Figure 4.

Figure 2: Shelf-life remaining for Darfresh product stored at 2.1 °C as predicted by Keep-It indicators (- - - -) and the Utas model (- - - -). Change in the aerobic plate count is shown by the solid line. The red square is where product odour and colour were considered unacceptable. Gray line is the daily temperature reported.

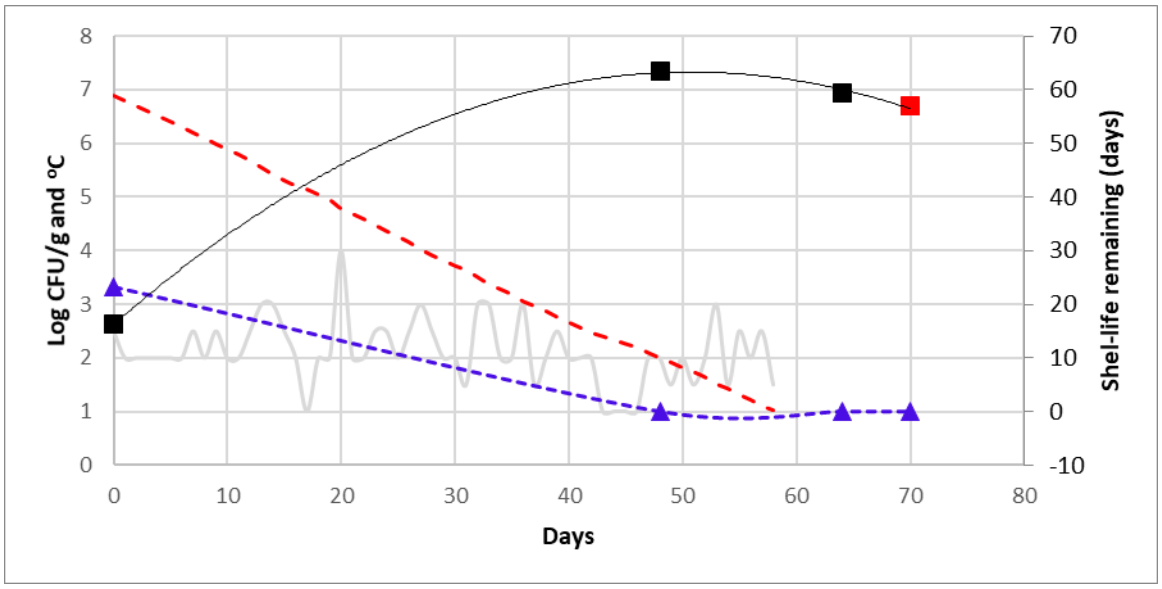


Figure 3: Shelf-life remaining for Darfresh product stored at 6.6 °C as predicted by Keep-It indicators (- - - -) and the Utas model (- - - -). Change in the aerobic plate count is shown by the solid line. Gray line is the daily temperature reported.

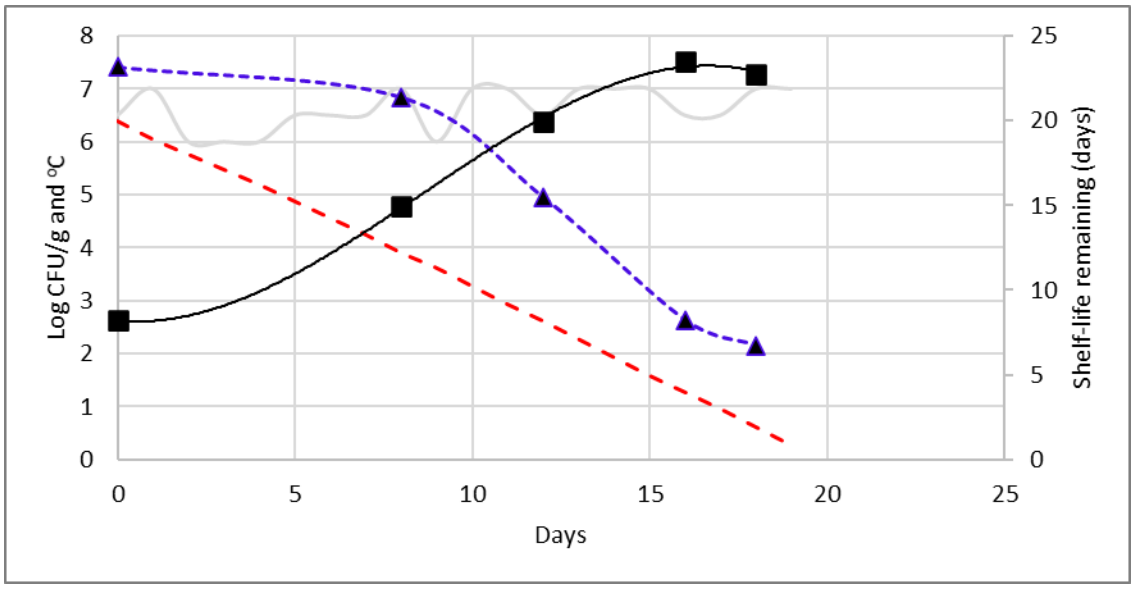
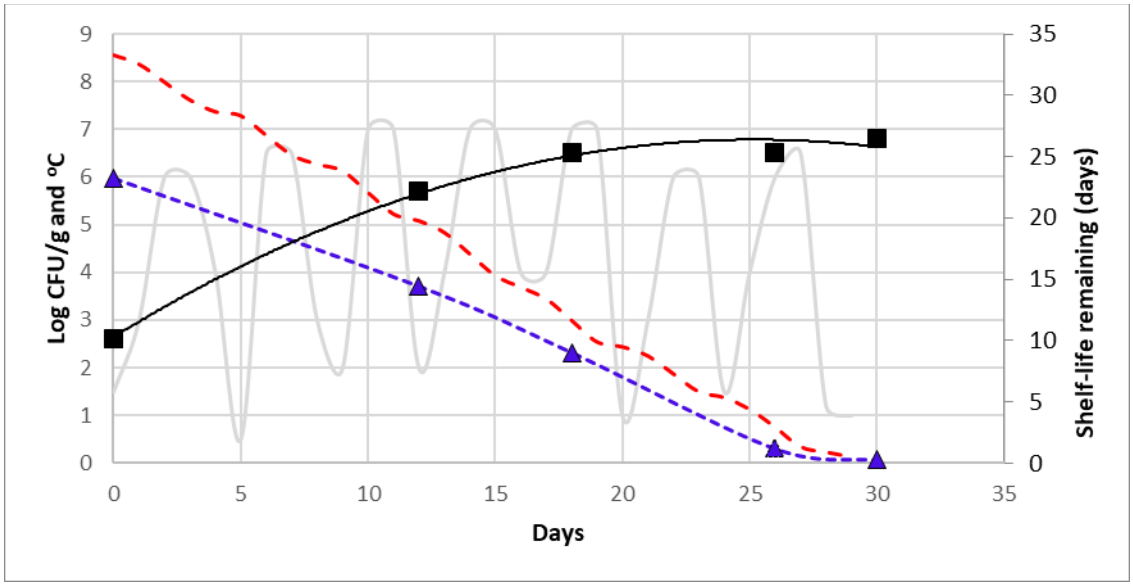


Figure 4: Shelf-life remaining for Darfresh product stored under fluctuating temperature between 2.1 and 6.6 °C as predicted by Keep-It indicators (- - - -) and the Utas model (- - - -). Change in the aerobic plate count is shown by the solid line. Gray line is the daily temperature reported.



The results show that both the UTas model and the Keep-It indicators underestimate the shelf-life remaining at low temperatures, with both indicating product stored at 2.1 °C had spoilt before there was any reported deterioration in the colour or odour. While both underestimated the shelf-life at 2.1 °C the Utas model (60d) performed better than the Keep-It indicators (<48d). Both the UTas model and the Keep-It indicators gave similar predicted shelf-life when the product storage temperature fluctuated between 2.1 and 6.6 °C (Figure 5) and for product stored at 6.6 °C (Figure 4).

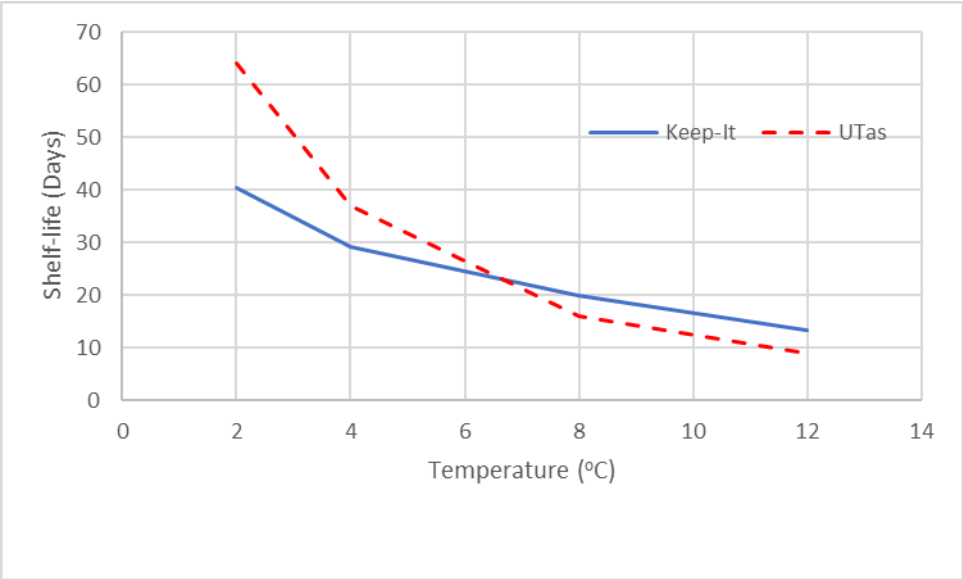
A summary of the Keep-It and UTas predictions for shelf-life at all temperatures are provided in Table 4.

Table 4 - Shelf-life remaining (days) calculated using the Keep-It indicator and UTas model compared to the organoleptic shelf-life as determined by an assessment panel.

	Predicted shelf-life (days)		
Temperature	Keep-It	Utas	Organoleptic
2.1 °C	<48	57	~64
6.6 °C	>18	~20	>18
2.1-6.6 °C	~30	~30	>30

Interestingly, results from Norwegian trials at 2, 4, 8 and 12 °C show that the Keep-It indicators underestimate the shelf-life at low temperatures and overestimate it at high temperatures when compared to UTas predicted shelf-life (**Figure 5**). This supports the findings in the current study. This variance may be due to the indicators not being calibrated for Australian product.

Figure 5: Observed shelf-life remaining as determined by Keep-It indicator readings (Norwegian data) as compared to predicted shelf-life remaining as determined using the Utas model (- - - -).



The results shown in figure 6 indicate that the Keep-It technology is effective at forecasting the expiration of Australian Red Meat products. We know from existing Norwegian white papers that the Keep-It technology must initially be calibrated to the relative product's expiration profile. This is evidenced also through the existing application ranging from frozen to chilled breads, flowers, pharmaceuticals and various meat and seafood items.

4.2 Retail supply chain

The actual temperatures which red meat products are held is important for the shelf life integrity however unless we can determine the result of this temperature record, the information is considered as noisy data. The Keep-It Indicator allows for a quick, easy to read quality check at store level to ensure supply chains are acting as they are expected. This is the most obvious justification that Keep-It Indicators objectively benefit the red meat supply chain in Australia. Temperature Data Loggers are more suitable for use by higher management after a supply chain issue has been identified and action to amend the issue is taken.

No data points taken from the Keep-It Indicators were excluded from the study. 1,426 data points from the Temperature Data Logger were excluded from the study because they showed temperatures indicating the logger had already been removed from the supply-chain (32.9% of the 4,334 total considered data points sampled). This can be seen in Table 5, which includes a summary of data points assessed. The information displayed within this table can be further referenced in the results section of the report. Adjusted acceptance is based upon the information in Table 6 in conjunction with table 1.

Table 5 – summary of key data points assessed.

	Volume of data points	Days of data available (% of shelf life)	Time of day data received	Speed of data transfer	Adjusted Acceptance
Temperature Data Logger	2908	20.7%	3pm	> 72 hours	50.000%
Keep-It Indicator	46	79.3%	avg. 7:45am and 5:00pm	< 5 minutes	87.500%

4.2.1 Category 1: Analysis of the ability to rapidly identify supply chain issues.

Speed of information transfer was the highest priority. The assumption was that if a real-world quality issue was suspected, action would be taken to prevent the same issue repeating.

In the trial period, the Keep-It Indicators gave a real-time assessment of the shelf life remaining to in-store staff and therefore had the best ability to give various stakeholders within a Retailer and Producer organisation the direction as to where further resources (such as data loggers) needed deploying. While using Keep-It Indicators, if multiple products were displaying unacceptable shelf life quality the problem could be escalated to higher management for action. The Temperature Data Loggers were unable to provide any useable information to in-store staff because of a requirement for providing a computer program to extract the data, and then having training for staff to understand the response of a perishable product to the various temperatures it was held at.

Table 6 – measurement objectives and acceptance levels of both technologies.

Measured Objective	Temperature Data Logger		Keep-It Indicator	
Volume of data points	Acceptable	2	Marginal	1
Days of data available (% of shelf life)	Marginal	1	Acceptable	2
Time of day data received	Marginal	1	Acceptable	2
Speed of data transfer	Unacceptable	0	Acceptable	2
		4		7

Key discussion items of the measured objectives in Table 6 are identified below, with the discussion linking each data point's relevance to a speedy analysis of supply chain issues.

1. The volume of data points for assessing a supply chain issue were considered only marginal for Keep-It Indicators because of the vast spread between that technology and data loggers. That is, Data Temperature Loggers were set to take a recording at 1 minute intervals. In theory, Keep-It Indicators have continual and uninterrupted monitoring but the monitoring is only done on a twice daily basis. This can be improved upon if closer monitoring is required.
2. The total days of data available from the Keep-It Indicators is twenty three (79.3% of the total shelf life as seen in **Table 5 – summary of key data points assessed.**). The first three days of data were non-visible information while the products are in transit and stored in cartons. If a supply chain issue were identified at a store level, it would be assumed that transit and/or stored cartons of the same batch are opened and assessed, still identifying a supply chain issue more rapidly than a Temperature Data Logger[8]. Therefore that category was identified as being acceptable. The days of visible data for a Temperature Data Logger was six (20.7% of the total shelf life as seen in **Table 5 – summary of key data points assessed.**). Despite the low visibility of the supply-chain, this data was assessed as marginal due to the early stage of the product's life which it contained.
3. The time of day for information transfer was considered marginal and the speed of data unacceptable for the Temperature Data Logger because this technology has multiple steps to complete. Some of the steps necessary to return a data logger are unpredictable. A typical chain of events includes store managers removing the logger from the supply chain, sending it via a back-load truck or postal system and then assumes that management has the time to analyse it. These two measurement items "Time of day data received" and "Speed of data transfer" have been connected for the written summary because one is not complete without the other. Speed of data transfer and the time of day for information transfer for Keep-It Indicators was considered "Acceptable" because it was determined by the time a store staff member took the sample and shared it with management. This can be adjusted by store process.

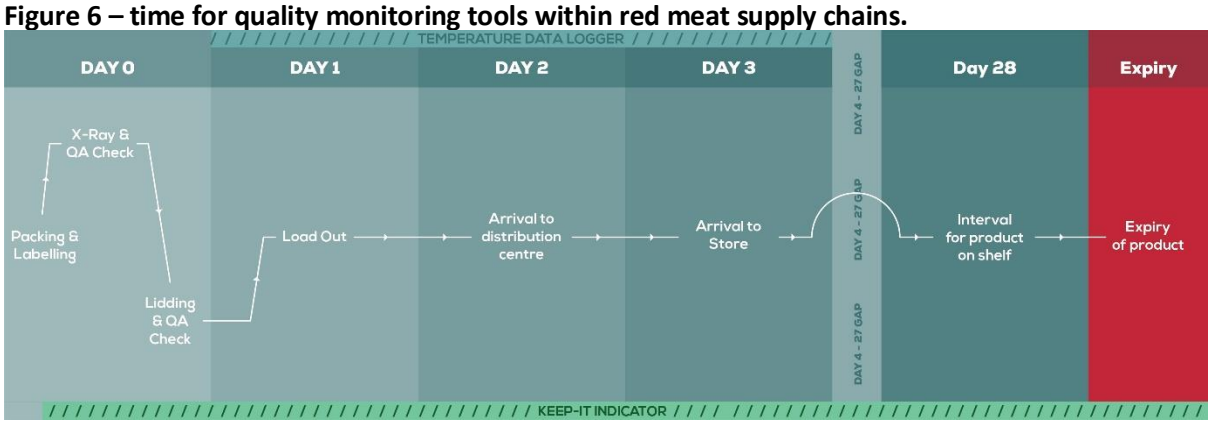
4.2.2 Category 2: Analysis of Waste and Waste reduction considerations, leading to the optimised shelf life of products.

This analysis category aims to bring together existing QA shelf-life forecasting with real time information of the quality for products within the Australian red meat supply chain. The Keep-It Indicators were able to give a 100% sample of the shelf life of various products if instructions for monitoring the progress were directed to this specific objective[9]. This information could be assessed by QA teams when decisions of future expiry or use by dates are to be set. The Keep-It Indicators are not as accurate as Temperature Data Loggers due to the presentation of information in a readable timeline format. Temperature Data Loggers are highly accurate, however lack the ability to show real shelf data to QA teams unless "real" practices are changed to allow the inclusion of the logger, such

[8] The data for Keep-It Indicators was also not visible after consumer clients purchased the meat (after day 23 of the shelf life).
[9] Refer to infographic in Figure 8 (reduction in beef shelf life during storage)

as bypassing X-Ray machinery and the requirement of QA staff needing to be trained in order to use the shelf life model and effectively understand the temperature and timeline format.

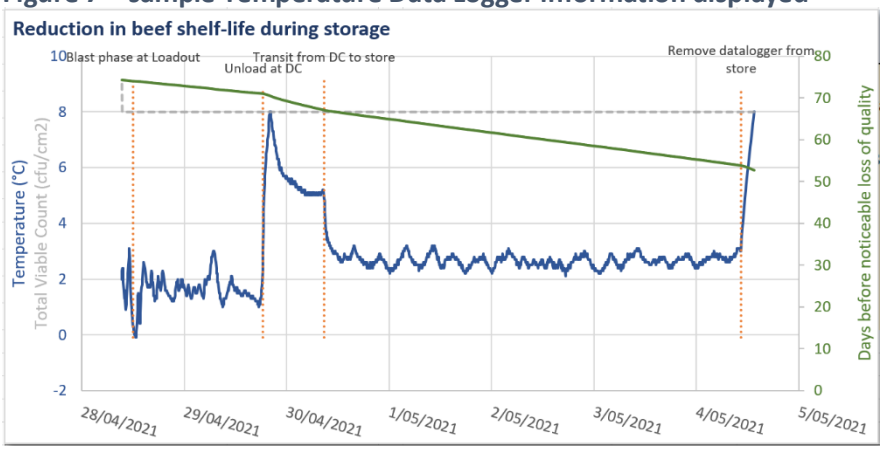
Figure 6 – time for quality monitoring tools within red meat supply chains.



Of the information retrieved from the data logger, only an average of 1.26 chronological days passed between the blast cycle at load out until unloading the consignments at the Retailer's DC, and in a real-world scenario this would remain quite consistent with trucking schedules and suppliers. This is a critical time within the supply chain, but the real variability comes from those factors which are harder to control or are completely out of the control of Retailers. Items such as weather events, different store staff, and even transferring between the product's unique seasonal offers or promotional sales affect the time on shelf and relative handling.

Figure 7 is an infographic showing the time for each technology within the supply-chain. Here it is seen that 79.3% of the product's shelf life witnessed was on-shelf or in the consumer's care. It has been recognised in the UTAS model that with a 5^{o} Celsius increase in temperature we can expect to approximately half the shelf life. Therefore, having the Keep-It Indicator present on each package was considered more beneficial to the retailer in analysing waste and stop loss than the use of a temperature data logger. Optimising shelf life is achieved through consistent store processes and having a measurable quality tool to base these processes on.

Figure 7 – sample Temperature Data Logger information displayed



The study was undertaken in a working retail environment, so the volume of Keep-It indicators available to capture was decreased as the study progressed due to customer sales.

4.2.3 Temperature Data Logger V's Keep-It Indicator results[10]

- Temperature Data Logger information is highly accurate when correctly handled. Maximum data points (500 data points per 24hr period) were achieved with Temperature Data Loggers, however the speed of information transfer was the limiting factor. This is expanded upon within section 4.2.3.1 Interval of time in supply chain of this report. There was a lot of data removed from the assessment as it was recorded after the logger was removed from the supply chain, and when expounding this across multiple sites and products makes the management of small supply chain issues more difficult to analyse and amend where necessary.
- Keep-It Indicator results could be considered subjective at a store level due to the fact "best before" dates are retained on products and there is a possibility for variances between the two dates if temperatures differ from prediction. This subjective nature could be removed through a simple store process instruction and ensuring action plans are understood.
    - The variance needs to be identified as either surpassing or underperforming expectation of product and supply chain quality expectations.

4.2.3.1 Interval of time in supply chain[11]

- In Table 6, Days recorded via the Temperature Data Logger showed that only 20.7% of the supply chain was visible in the assessment.
- Days recorded via the Keep-It indicator were theoretically 100% of the time available to sell the products. Because the milestone was completed in an operating retail environment, the volume of packs with the same expiry date towards the end of the study period was decreased as sales were made. On day 27 of the 29 viable days for sale, there were no packs remaining on shelf. This was explained further in section 4.2.1 of this report.

4.2.3.2 Visibility of Supply chain results

- The Temperature Data Logger results were considerably more detailed than results retrieved from Keep-It Indicators but were not visible to the store level staff due to the complex nature of understanding microbial response of meat to different temperatures. Prompt identification of supply chain issues and the resulting action assumes that management deems the data is required urgently. It also assumes that the staff member who is capable of reading the data and making informed decisions is present at the time the loggers are available.
- Keep-It Indicators are a simple tool for in-store staff to rapidly identify supply chain issues to management teams. The information provided can better the QA team's shelf life optimisation of shelf life and therefore contribute to minimising waste and stop loss.

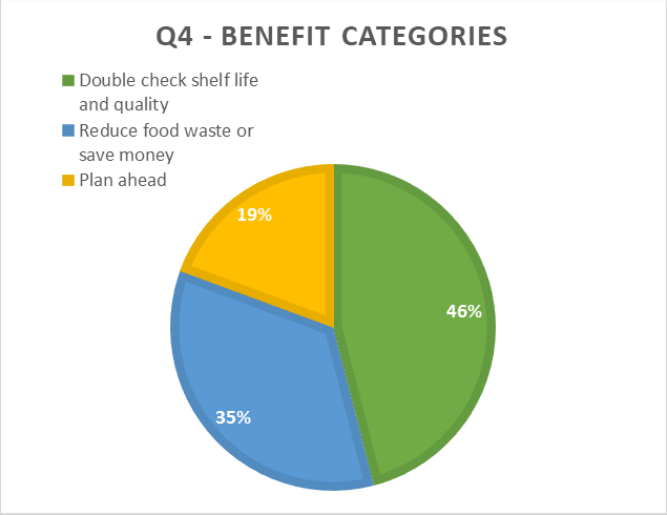
[10] Recorded as "Volume of data points"
[11] Recorded as "Days of data available (displayed as a percentage of the product's total shelf life)"

4.3 Retail consumer response

The results of the consumer study showed that Keep-It Indicators are perceived by consumers as a positive advancement for the Australian red meat industry and retail environment. This was recognised on both an economic and environmental perspective. We identified the main motivation (46%) for consumers was sustainability and environmentally focused. Those which were in the "Plan ahead" category would become a swing vote either way. Economically focused respondents comprised 35% of the study. This validated the design of the study in obtaining a diverse population as seen in figure 8.

The core issue faced with the retail consumers studied was a lack of proper knowledge prior to the study taking place. Similar results were learnt during larger European studies where a minimum of 479 respondents were surveyed. The major difference between studies is that the Australian consumers were overall more positive about the retailer's intention for implementing the indicators in their supply chain.

Figure 8 – Benefits identified by consumers.

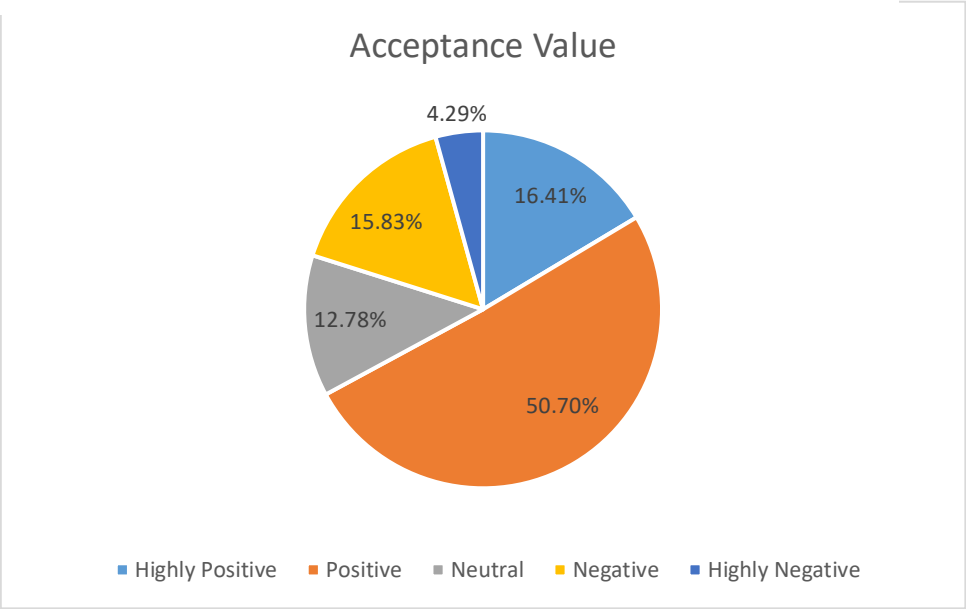


A key question used to identify this is question 7 of the Questionnaire[12]. This question asked respondents why they thought the retailer was using the Keep-It indicator. Despite the results needing to be cleaned for adequate measure, the single and most transparent negative option "It's just a PR stunt, or a gimmick" was not selected by any of the respondents.

Consolidated data in figure 9 shows responses to all questions with an association of Highly Positive, Positive, Neutral, Negative and Highly Negative in a quantitative representation of the qualitative dataset.

[12] Refer to Appendix section 8.3.1

Figure 9 – Percentage of acceptance values for all survey questions



It was found that more than half of consumers surveyed have a positive perception of the Keep-It technology and the associated economic and environmental benefits. 16.41% of responses were in a "highly positive" opinion for the Keep-It technology overall. This in comparison with a 4.29% "highly negative" opinion. Regardless of their opinion, consumers seemed to have a lack of knowledge for how industry currently sets expiry dates for products. Due to the ease of reading the expiry remaining, consumers felt more comfortable that they were making an informed purchasing decision

5 Conclusion

It was found that industry adoption of Keep-It would ensure that any new and existing technologies to improve processes are supported by a real time quality measurement.

Currently there are label and sensory technologies available to increase efficiency of the supply chain and ensuring temperature sensitive products are only sold within their expiry period. These technologies do not incorporate a quality assessment of how the product has been handled, and the response of this handling to the real shelf-life available. Due to the ease of application on products and simplistic information transfer, the Keep-It Indicator is well placed to make communication between stores and management simple.

Regardless of implementation of a Keep-It indicator on products within a retailer's supply chain, it is recommended that extra attention is paid to the in-store management of Australian red meat supply chains during the Summer months (notably February) while temperature and humidity levels are more likely to impact a product's quality.

5.1 Key findings

5.1.1 The accuracy of Keep-It indicator shelf life prediction

The storage trial undertaken demonstrated that the Keep-It technology was as good as the UTas model in predicting the remaining shelf-life at 6.6 °C and when the storage temperature fluctuated between 2.1 and 6.6 °C. The Keep-It technology performed best when the storage temperature fluctuated between 2.1 and 6.6 °C. This is consistent with Australian red meat supply chains. The Keep-It indicators did better at predicting the observed shelf-life than the UTas model at 6.6 °C. On the basis of the technology alone, there is a high benefit to be derived from implementing the use within Australia.

It should be noted that Keep-It technologies would do a full Quality Assurance assessment of unique products and assign a relative shelf-life profile that matches it at the time of implementation within a supply chain. Due to the different microbiological factors between Australian meat production and the existing database of shelf-life profiles used in this study, the exact correlation between Keep-It and UTas model was not met.

5.1.2 Use of Keep-It indicators through the retail supply chain

When assessing the usage and acceptance of Keep-It indicators against two key categories it was found that overall, the Keep-It technology is superior to using traditional supply chain management tools such as Data Loggers.

When considering Category 1: *Analysis of the ability to rapidly identify supply chain issues*; the acceptance level is 87.5% in comparison to 50% for the data logger equivalent. This was largely attributed to the speed and ease of data communication. Alongside of the complete volume of data throughout the total supply chain.

When considering Category 2: *Analysis of Waste and Waste reduction considerations, leading to the optimised shelf life of products* it was found that the Keep-It indicator's presence on each package was more beneficial to retailers than the use of a temperature data logger. This was due to in-store processes being quickly fixed rather than escalating a problem which can otherwise be solved swiftly, if given the right information.

Whilst the technology is of a significant financial benefit to the retailer, it must be noted in conjunction with the current societal trends surrounding Environmental Social and Governance (ESG) principles of the business' stakeholders. This scrutiny of investor's business from their clients contains the wholistic food systems they interact with. Improving a carbon footprint impact of a retail business can be managed in a multitude of ways, and we are already seeing expansion in a preference of low-carbon-impact brands by consumers. The ESG trend is only starting and will invariably lead to businesses needing to answer questions on how their waste management practices are environmentally and carbon neutral. The Keep-It technology allows retailers to not only purchase carbon reduced products but also limit the waste they produce through a higher collaboration with their consumers.

5.1.3 The acceptance and potential benefits to retail customers

The Qualitative analysis of Keep-It indicators in a consumer study showed that there is a real, positive benefit associated with giving consumers enhanced information to make informed purchasing decisions. This was recognised on both an economic and environmental perspective.

It was found that consumers had one of two core values when shopping during the study period. This allowed us to categorise respondents as either (1) economically motivated or (2) having a sustainability and quality-based drive.

There was a mutual agreement between the two respondent groups that food waste in a household environment would be reduced because of using the technology. The environmentally categorised respondents were more positive about the financial benefit of implementing the technology, however there is a potential for some consumers to take advantage of the improved buyer knowledge and aim to purchase discounted products. This situation is already faced within industry at the current time, and there will always be a portion of the population looking to take advantage of near-expiry products for a discount. Adequate marketing before the release will be an important aspect to ensure the general population are aligned in achieving the proposed economic and environmental goals.

The behavioural impact of consumers towards the retailer is improved with the use of Keep-It technology, witnessed through a reduction in the amount of complaints and dissatisfaction after a purchase.

Consumers are more informed overall with the Keep-It technology, and the responsibility is put on them to practice sustainable purchasing and consumption. People who are not educated about food technology take date stamping as hard policy and will waste food without justification. It was seen during the study that consumers feel a moral obligation to do the right thing for the environment and Keep-It presents a comfortable way for them to do so. This technology creates a closer alignment to the retailer and invariably increases basket size along with increased regularity of shopping.

Consumer's response to the Keep-It indicators have an aligned perception to Retailer and Producer stakeholders within the Australian red meat supply chain according to an economic and sustainability criteria.

5.2 Benefits to industry

The practical application of Keep-It indicators within an industry setting is enhanced with scale. For larger-scale retail entities who have a close relationship with their meat packer suppliers, it is a simple addition to in-line production processes. After this point the technology is considered hands-off. For smaller-scale retail entities there is a slightly challenging application process due to each individual package requiring an additional step and the set-up cost per unit is exponential. For small scale applications it is harder to justify the labour component when compared to the existing alternative of Data Loggers. Smaller entities may be left at a considerable disadvantage when the technology is widely adopted however there is current development by the producer of the technology to improve this.

The most difficult point facing supply chain participants today is a scrutiny of practices by external stakeholders who do not understand the complexities surrounding the normal, high standards within Australia. The most significant wider benefit of Keep-It indicators to industry is that a retailer

is now able to claim multiple points of the UN's sustainable development goals[13] being met, with a minimal change to their supply chain practices.

6 Future research and recommendations

Alternative technologically based solutions continue to being trialled within red meat supply chain of Australia. These are largely data and computer based, showing the potential for these technological advancements to run in conjunction with the Keep-It technology and create a highly efficient retail supply chain.

Practical insights learnt from the research project include but are not limited to the following:

- Consumers want to "do their part" in creating sustainable supply chains.
- A closer collaboration between processors and retailers is essential in today's retail environment.
- Technological supply chain advancements need some level of Quality Assurance engagement to become effective.

It is recommended that any supply chain who implements the technology undertake the relative marketing exercises prior to the release. This will ensure a positive economic and environmental outcome is achieved. Dark trials should be undertaken with those supply chains which have a sceptical view of the current system's integrity, ensuring that consumer feedback is not damaging to their brand reputation whilst they improve practices. Regardless of the level of marketing employed before implementation of the Keep-It technology, there are a multitude of benefits to be made.

7 References

David McKinna and Catherine Wall (2020) Commercial application of supply chain integrity and shelf life systems. V.MFS.0447

MLA (2016) Shelf life of Australian Red Meat. https://www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/food-safety/pdfs/shelf-life-of-australian-red-meat-2nd-edition.pdf

TempTale Ultra Fit brand; CE, RTCA – D016ØG compliant, RoHS compliant, Response time tested to U.S. Pharmacopeia (USP) and EN 12830 standards

8 Appendix

8.1 Laboratory Validation

Declarations of compliance for the applicator and indicators were assessed prior to engaging in the study. These products comply with Regulation (EC) 1935/2004, (EC) 450/2009 and (EC) 2023/2006

A-PET laminate A-PET/PE

[13] https://sdgs.un.org/goals#goals

Indicator components: Indicator comprises I2 and starch. No components in scope (Above 0,001mg/indicator) are classified substances according to EC directives

O-PET laminate O-PET/EVA/PE

Adhesive Acrylic based

Machinery is rated IP 65.

8.2 Retail Supply Chain

7 retail stores were assessed during the study period.

8.2.1 One Page Overview

Product summary: Keep-It Smart Packs

What is Keep-It? An interactive Date Stamp which is a graphic representation of the days left on a fresh food product to indicate freshness and perishability. It can be applied in-line to any fresh food product in order to give retailers and consumers enhanced supply chain confidence above traditional static date stamped options.

Background: The product works as a function of time and temperature. It understands that supply chains have variance in temperature and that different products can handle certain levels of temperature abnormalities during goods handling. Formulated in Norway over 15 years ago and having a commercial application since 2012, the dynamic date stamp is designed to give further insight into the integrity of existing supply chains. Giving this information to consumers all the way to their refrigerator results in higher profitability and an increased consumer perception of sustainability for those companies utilising the Smart Packs. 2018 studies of the product effectiveness have shown an increase in basket size for stores with the smart-packs available. Products with the smart-pack technology have also seen a reduction in wastage from 25% to 60% depending on the SKU*. Increase in quality and food safety perception by customers of up to 10% in one year*. Major investors of the technology include Innovasjon Norge (the Norwegian Government) and the largest solar energy company in Scandinavia, Scatec.

Producer benefits:
• Increase Retailer support of brands through providing detailed supply-chain management and visibility.
• Decrease the risk of returns/claims due to storage and handling misuse.
• Better allocation of IT and QA staff resources and time (for example, directing data-loggers to those locations most needed).

Retailer benefits:
• Increase basket size through consumer confidence and meal planning.
• Increase consumer loyalty and foot traffic.
• Convert “waste” sales to “mark-down” sales, and “mark-down” sales to full ticket value sales

Consumer benefits:
• Greater meal-planning efficiency.
• Reduction of food-waste (UN’s Sustainable Development Goal 12.3) - currently 61% of all food wasted is occurring in the household.
• Higher confidence in the retailer’s integrity across all temperature sensitive products

Practicality of implementation:
• In-line application, taking up minimal space on a production line.
• Apply up to 120 units per minute of output.

8.3 Retail Consumers

8.3.1 Questionnaire

Questionnaire used in the retail component of the study.

Keep It market research interviews.

☐Male ☐Female
☐18 to 24 years old
☐25 to 34 years old
☐35 to 44 years old
☐45 to 54 years old
☐more than 65 years old

1. How often do you shop at this retail chain?

☐Often
☐Sometimes
☐Rarely
☐Never

2. Have you ever bought fresh food with Keep-It shelf-life indicators on the packaging?

☐Yes
☐No
☐Don't know

3. How often do you actively look for the Keep-It shelf life indicator?

☐Always
☐Often
☐Sometimes
☐Seldom
☐Never

4. What do you consider to be the main benefits of using the Keep-It indicator in your household?

☐Double check shelf life and quality
☐Reduce food waste or save money
☐Plan ahead

5. Would you eat a product if the indicator shows more shelf life days are remaining, but the static date stamp has passed?

☐Throw it away regardless
☐Eat it
☐Don't know

6. Do you think Keep-It has helped you reduce food waste in your household?

☐Very much
☐Moderately
☐Some what
☐A little
☐Very little
☐No change
☐Don't know

7. What do you think is the reason this retailer is using the Keep-It indicator?

☐Contribution to reduce food waste
☐Contribution to sustainable food production
☐Contribution to secure quality and freshness
☐It's just a PR stunt, or a gimmick
☐Don't know

8. Do you think the Keep-It indicator is important for you and your household?

☐Very important
☐Important
☐Somewhat important
☐Neutral
☐Not important

9. Do you feel secure that the food you buy is of good quality with Keep- It?

☐Completely disagree
☐Somewhat disagree
☐Neutral
☐Somewhat agree
☐Completely agree

10. Do you throw away less food with Keep-It?

☐Completely disagree
☐Somewhat disagree
☐Neutral
☐Somewhat agree
☐Completely agree

11. Do you think you save money with Keep-It?

☐Completely disagree
☐Somewhat disagree
☐Neutral
☐Somewhat agree
☐Completely agree

12. Do you feel safer about the food's shelf life and quality in your home refrigerator with Keep-It tags attached?

☐Completely disagree
☐Somewhat disagree
☐Neutral
☐Somewhat agree
☐Completely agree

13. Do you think you can safely buy discounted fresh food with short shelf life on the static date stamp?

☐Completely disagree
☐Somewhat disagree
☐Neutral
☐Somewhat agree
☐Completely agree

14. Do you think you can safely consume fresh food with expired date stamp if there are more days left on the Keep-It indicator?

☐Completely disagree
☐Somewhat disagree
☐Neutral
☐Somewhat agree
☐Completely agree

Date:
Location:

8.3.2 Split of Economic and Sustainable priorities

A graphical representation of the split Economic and Sustainable categories is shown below.