Final report

Australian beef shelf life verification trial

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Abstract

Australian vacuum-packed (VP) chilled beef has a practical storage life of 140 days when stored below 0 °C. In Egypt, much shorter limits of 49 days for boneless and 28 days for bone-in beef are prescribed, which restricts market supply of Australian beef. This study was designed to verify that Australian boneless (striploin) and bone-in beef (Oven Prepared rib) primals display satisfactory sensory properties throughout extended cold storage in Egypt. A secondary aim was to assess whether Egyptian Standard quality criteria are suitable predictors of sensory (organoleptic) properties of Australian beef. VP primals, collected at slaughter from an Australian export establishment, were transported to a CSIRO laboratory for baseline testing or air freighted to Egypt for extended cold storage (0 to -1 °C). Primals were tested for meat quality indicators at eight timepoints across 133 days. Both bone-in and boneless primals were organoleptically acceptable to an Egyptian panel until 126 days, even though most Egyptian Standard quality limits were exceeded. This suggests that shelf life limits could be relaxed. Extending shelf life limits would reduce freight costs and waste in supply chains, provide opportunities for Egypt to develop food manufacturing (export) businesses and create new markets for Australian export establishments.

Executive summary

Background

Shelf life limits applied to boneless (49 days; 7 weeks) and bone-in (28 days; 4 weeks) chilled vacuum-packed (VP) beef in Egypt are much shorter than the 70 to 120 day limits prescribed by some countries in the Gulf region. The criteria and limits used in Egypt to assess the shelf life of VP beef may not be appropriate for Australian beef, which has been shown to achieve a shelf life of 140 days or more when stored appropriately. To demonstrate that Australian product remains acceptable under extended cold storage, a verification trial is needed to assess "real world" shipping and extended storage of Australian VP primals in Egypt.

Objectives

This study was designed to verify that Australian boneless and bone-in beef primals display satisfactory sensory properties that meet consumer demand in presentation, cooking and eating quality when stored up to 133 days (19 weeks) and that product remains acceptable when quality criteria exceed the acceptable limits prescribed in the Egyptian Standard Specification (ESS) (Egyptian Organisation for Standards & Quality, 2013).

Methodology

Bone-in (Oven Prepared ribs, referred to as OP ribs) and boneless (striploin) Australian VP primals were collected at slaughter from an Australian abattoir and transported to a CSIRO lab in Brisbane for baseline testing or air freighted to Egypt for extended cold storage and testing. Three pieces of striploin and OP ribs were removed from cold storage and tested for a range of meat quality indicators in Australia soon after collection (week 0) and in Egypt at each of seven storage time points; on arrival until 133 days (19 weeks). Quality indicators were selected from Egyptian Standards (Egyptian Organisation for Standards & Quality, 2013) and included: the total viable count (TVC) on surface tissue, the concentration of total volatile basic nitrogen (TVB-N) and thiobarbituric acid reactive substances (TBARS), the drip percent and meat pH. The vacuum integrity and sensory properties (appearance, odour and eating quality) of samples were also assessed at each timepoint.

Results/key findings

Australian OP ribs and striploin were shown to have acceptable sensory (organoleptic) properties until 126 days (18 weeks) of cold storage and the product remained within most Egyptian Standard limits for the majority of the period of organoleptic acceptability. At 126 days (18 weeks) both primals displayed acceptable sensory properties even though the mean drip percent, meat surface TVC and TVB-N values exceeded the ESS limits. Mean TBARS increased gradually over the course of the trial but remained within permissible limits of the Egyptian Standard Specifications until 133 days of storage for striploin and 126 days of storage for OP ribs. Likewise, mean pH values remained within permissible limits for the duration of the trial

Benefits to industry

Increasing the shelf life of vacuum-packed meat in Egypt would provide many opportunities for businesses in Australia and Egypt including reduced freight costs in supply chains, provision of quality products at lower prices, and opportunities to grow and develop food manufacturing businesses. The results reinforce the superior shelf life attributes of Australian beef and contributed to the overall Australian beef industry objective to create new market opportunities or cost savings by 2030.

Future research and recommendations

The findings show that Australian VP beef can remain acceptable at 0 to -1°C for periods that far exceed current Egyptian shelf life limits. A number of quality indicators exceeded allowable limits in product with acceptable sensory properties, which suggests that these limits may not be appropriate for Australian product. Therefore, Egypt shelf life limits and quality criteria should be reviewed and revised as appropriate. The findings suggest that shelf life limits of 49 days (7 weeks) for boneless and 28 days (4 weeks) for bone-in product (stored between 0 to 2 °C) could be extended to 126 days (18 weeks) if product is stored under the conditions tested (0 to -1 °C). Under these conditions, Australian VP beef is expected to be acceptable to consumers up to and beyond 18 weeks. A revision of the shelf life limit to 120 days (17 weeks) would be consistent with shelf life limits imposed by some countries in the Gulf region.

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1. Background

In 2018-2019, the majority of Australia's beef and veal production was exported to more than 70 countries, making Australia the world's third largest exporter in this category (Meat & Livestock Australia, 2019). For fresh beef products to be a viable export option for industry and customers, an extended shelf life is essential. Australia has made large investments in research over many years to understand how product deteriorates and how conditions can be manipulated to increase the shelf life of fresh meat (Meat & Livestock Australia, 2016). The results of these studies have shown that Australian vacuum-packed (VP) boneless beef primals and sub-primals may achieve a shelf life of up to 140 days (20 weeks) when stored under controlled conditions. The Australian industry have optimised their processing and supply chains to maximise shelf life and Australia has an excellent reputation for producing fresh beef products with extremely long shelf lives. By managing cold supply chains, it is possible to extend the shelf life of fresh vacuum-packed beef under real world shipping conditions. For this to be achieved, specific meat attributes and long-term storage criteria are required. These include:

- Low initial total viable counts of between 2 and 3 $\log_{10}$ cfu cm^{-2} of surface meat at the time of processing
- Low meat pH values <5.7 at slaughter
- Low oxygen transmission rates through cryovac bags
- Controlled storage temperature of 0 °C to -1 °C

Shelf life limits on Australian beef vary by country and customer. For countries in the Gulf, a minimum shelf life of 70 days (10 weeks) is applied to vacuum-packed chilled meat with some applying 90 days (12 weeks) and the UAE applying 120 days (17 weeks). In June 2018, the Standards Organization of the Gulf Cooperation Council (GSO) notified the WTO about a revision of the GSO standard GSO150-1:2013 (Standards Organization for G.C.C (GSO), 2013) which identified the shelf life of food products. This draft revision of the standard applying in the GCC countries (GSO FDS 150-1/2018) identified the following proposed shelf life for beef: Red meat (beef) vacuum-packed - 120 days of the slaughter date.

In Egypt, a much shorter shelf life is applied to vacuum-packed meat. Boneless primals held at temperatures between 0 and 2 °C have a prescribed shelf life of 49 days (7 weeks) from slaughter date, while bone-in products have a 28 day shelf life (Egyptian Organisation for Standards & Quality, 2008). Increasing the shelf life of vacuum-packed meat would provide many opportunities in Egypt to develop food manufacturing (export) businesses and to provide quality products at lower prices. Beef that remains fresh for longer durations will also help to reduce product wastage throughout the supply chain. This trial aims to work collaboratively with Egypt to verify a number of criteria used to determine an extended shelf life for vacuum-packed red meat, including:

- That vacuum-packed beef stored at 0 to -1 °C for extended periods (up to 133 days/19 weeks) will meet consumer demand in presentation, cooking and consumption.
- That appearance and sensory properties of beef will remain acceptable when the following Egyptian Standard Specification limits are exceeded:
  - Total viable count (>6 $\log_{10}$ cfu cm^{-2})
  - Volume of or fluid "drip percent" in a vacuum-packed meat product (>2 % weight/weight)
  - Total Volatile Basic Nitrogen concentration (>20 mg/100 g).
  - Thiobarbituric acid reactive substances (>0.9 mg/kg Malonaldehyde (MDA) eqv.)

2. Objectives

The agreed objectives, extent to which each was achieved (achieved, partially achieved etc), and a brief summary of how objectives were achieved are provided below.

1. Assist MLA in agreeing on tests and test methods to be used during shelf life verification trials with Egyptian authorities.
   Achieved: Methods were prepared in consultation with staff from MLA Middle East and Sydney offices and the Animal Health Research Institute, Cairo.

2. Liaise with the exporter selected by MLA to ensure that product is packed according to specification, samples are collected, and temperature loggers placed in the shipment.
   Achieved: CSIRO liaised with Australian processor personnel to ensure samples were collected and packed according to specification. CSIRO coordinated with personnel to support sample collection and ensure temperature loggers were activated and placed into cartons prior to shipment.

3. Test representative samples of product at the time of packaging to establish zero-time data.
   Achieved: Representative samples were collected by CSIRO and transported to the Coopers Plains facility for processing of week zero samples. Samples were processed according to agreed methodology, results were analysed and reported to MLA as part of milestone 2.

4. Assist MLA in collating materials from Australia and Egypt into a final report.
   Achieved: The final report was prepared by CSIRO using data provided by MLA.

3. Methodology

3.1 Packing and distribution

A suitable Australian processor with existing supply networks in Egypt for halal-certified vacuum-packed (VP) chilled beef was selected. Two primals, representing bone-in and boneless, were selected from the longissimus muscle for inclusion in the trial: bone-in Oven Prepared rib (OP rib) and boneless striploin. Primals were prepared according to the processor's specification manual, under the conditions of the Australian Standard (AS 4696), to the following specifications:

- Striploin (AUS-MEAT Handbook of Australian Meat reference code 2142) (Aus-Meat, 2005) "were prepared from a hindquarter by a cut at the lumbo sacral junction to the ventral portion of the flank. The flank was removed at a specified distance from the eye muscle (M. longissimus dorsi) at both cranial and caudal ends." (Figure 1.).
- Oven prepared rib (OP rib) (AUS-MEAT Handbook of Australian Meat reference code 1605) (Aus-Meat, 2005) "were prepared from a rib set by the removal of the short ribs approximately 75 mm from the eye muscle at the loin end, parallel with the vertebral column." (Figure 1.).

Figure 1. Vacuum-packed striploin (A) and Oven Prepared rib (B) primals used in the trial

Primals were collected from grain fed, human growth promotant-free animals during processing on the 26th Nov 2019. Primals were vacuum-packed in cryovac bags and placed into large cartons suitable for chilled transport. Striploins were placed three per carton for a total of nine cartons (n=27) and OP ribs were placed four per carton for a total of nine cartons (n=36). A combination of Tive and Sensitech data loggers, with different recording durations of 30, 90 or 180 days, were placed in between primals in nine of the 18 cartons – one logger per carton (**Table *1*** and **Figure *2***.). A single carton of striploin and OP ribs were immediately transported on ice to the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Coopers Plains, Brisbane, Australia for week 0 testing. Samples were placed at -1 °C upon arrival at CSIRO and assessed for freshness the following day.

Table 1. Details of temperature data loggers

Logger ID	Manufacturer	Model	Carton ID	Product type	Expected temp log duration (days)*	Achieved temp log D=duration (days)ǂ
A21159	Tive	Tive Solo (TT-5000)	2424	OP ribǂ	30	16
A21425	Tive	Tive Solo (TT-5000)	2027	OP rib	30	20
A21823	Tive	Tive Solo (TT-5000)	2438	OP rib	30	24
A21849	Tive	Tive Solo (TT-5000)	2251	Striploin	30	15
A21850	Tive	Tive Solo (TT-5000)	2172	Striploin	30	22
GH11101KF1	Sensitech	TempTale Geo Eagle	2184	Striploin	90	90
GH11101JT1	Sensitech	TempTale Geo Eagle	2169	Striploin	90	90
GH11101KZ1	Sensitech	TempTale Geo Eagle	2407	OP rib	90	90
T00675	Tive	-	2315	Striploin	180	92
T41419	Tive	-	Chiller rack	-	180	34

*Expected duration of temperature recordings for each data logger.
ǂObserved duration of temperature recordings for each data logger.
ǂOven Prepared ribs

Figure 2. Data loggers used in the trial

The remaining 16 cartons were stored at the processor until they were ready to be air freighted to Egypt. On arrival, cartons were stored under refrigeration (0 °C to -1 °C) at the Animal Health Research Institute (AHRI), 7 Nadi Al Saeed, Ad Doqi, El Omraniya, Giza Governorate, Egypt. Three pieces of striploin and OP rib were removed from cold storage for testing at each of seven storage time points, on arrival until 133 days (19 weeks). Test 1 was conducted in Australia and all remaining tests were completed in Egypt as follows:

- Test 1: 0 days (0 weeks) after the date of slaughter
- Test 2: 14 days (2 weeks) after the date of slaughter (on arrival in Egypt)
- Test 3: 56 days (8 weeks) after the date of slaughter
- Test 4: 98 days (14 weeks) after the date of slaughter
- Test 5: 112 days (16 weeks) after the date of slaughter
- Test 6: 119 days (17 weeks) after the date of slaughter
- Test 7: 126 days (18 weeks) after the date of slaughter
- Test 8: 133 days (19 weeks) after the date of slaughter

3.2 Success criteria

Test parameters and success criteria listed in **Table *2*** were used as a basis for determining the success of the shelf life trial. Where available, physical, chemical, appearance and odour limits were applied according to Egyptian Chilled Meat Standard Specifications (Egyptian Organisation for Standards & Quality, 2013).

Table 2. Test parameters and success criteria

Test	Parameter	Success criterion	Egyptian Standard ESS: 3602/2013 section	Rationale
Microbiological deterioration of product	Total viable count (TVC) of surface muscle	≤6 log_{10} cfu cm^{-2} of the meat surface*	3/2/21	This parameter is being reviewed in this trial and might be removed from the criteria for vacuum-packed meat because Australian experience shows: • no deterioration of product wholesomeness is likely to be observed when total bacterial count is 6 log_{10} cfu cm^{-2}. • Reaching the maximum total bacterial count is likely to occur some weeks prior to significant deterioration in wholesomeness.
	TVC of drip	Not defined	Not stipulated	
Physical and chemical deterioration of product	pH	5.4 to 5.8	3/2/17	These parameters may change slowly during the shelf life of the product. These parameters are being reviewed in this trial to determine whether they predict the sensory (organoleptic) assessment of the product.
	Total volatile basic nitrogen	≤20 mg/100 g	3/2/16	
	Thiobarbituric acid reactive substances	≤0.9 mg Malonaldehyde/kg	3/2/18	
	Drip	≤2 % (weight/weight) dripping liquid inside the chilled meat packages packed without absorbing pads	3/2/6	This parameter is being reviewed in this trial through measurement during the trial – Australian experience shows that the volume of drip will not predict the wholesomeness of product.
Consumer acceptance - appearance and odour	Appearance (intact pack) Appearance (30 min after opening the pack)	No detectable viscous matters, microbial growth, damage or decomposition. Assessed on 9-point scale from 0 (severe discolouration) to 8 (very fresh, no discolouration)	3/2/4	These measures are the ones that a consumer uses to judge the wholesomeness or the suitability for human consumption. When any one of these parameters is considered to be unacceptable to a majority of consumers, then the product may be considered to have reached the end of its shelf life
	Odour (on opening) Odour (30 min after opening the pack)	No detectable unpleasant odours. Assessed on 9-point scale from 0 (extreme off odour) to 8 (fresh,	3/2/5	

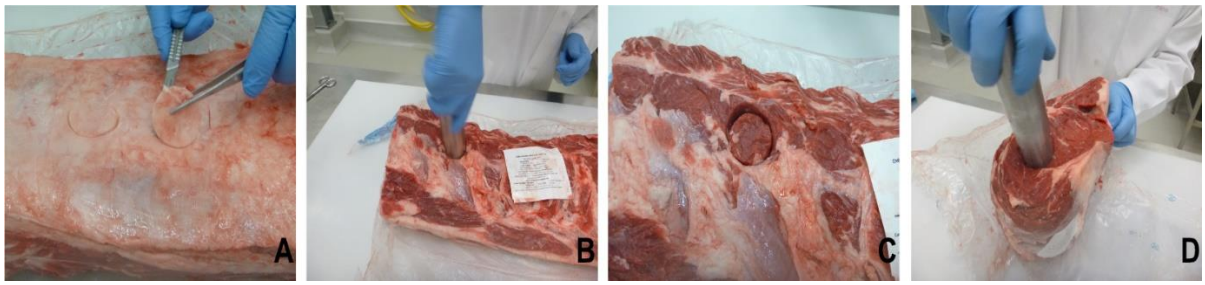
Test	Parameter	Success criterion	Egyptian Standard ESS: 3602/2013 section	Rationale
		no off / confinement odour)		
	Vacuum integrity	Assessed on 9-point scale from 0 (no vacuum, probable leaker) to 8 (complete vacuum, tight package adhesion)	Not stipulated	
Consumer acceptance - sensory (eating quality)	Tenderness Juiciness Liking of flavour Overall liking	Assessed on a 100 mm line scale (MSA evaluation sheet below). Scores above 50 for any criteria were considered acceptable.	Not stipulated	As above
	Quality	Assessed on 4-point scale from 0 (unsatisfactory) to 4 (premium quality)		

*As per original agreed methodology (MS2), total viable counts are reported in surface area (cm^2) units.

3.3 Microbiology

Surface slices and drip samples from striploin and OP rib primals were analysed for total viable counts using a standard plate count method. Four × 10 cm^2 surface slices comprising two subcutaneous fat and two lean portions of meat were excised from each primal (Figure 3.). All four surface slices (40 cm^2 total) were combined with 100 mL of 0.85 % saline in sterile bags and stomached for 1 min. Decimal dilutions were prepared from stomached and drip samples and a 1 mL aliquot of each decimal dilution was used to prepare pour plates according to ISO 4833-1-2013 (International Organization for Standardization, 2013). Pour plates were incubated aerobically at 30 °C ± 1 °C for 72 ± 2 h. Microbial counts were converted to $\log_{10}$ cfu cm^{-2} for surface samples and $\log_{10}$ cfu mL^{-1} for drip samples.

Figure 3. Excision of surface slice samples for microbiological assessment. Two cores were excised from striploin subcutaneous fat (A) and lean meat (B and C) surfaces and from Oven Prepared rib subcutaneous fat and lean meat (D) surfaces.



3.4 Physical and chemical characteristics

3.4.1 pH measurement

Meat pH was measured using an electrometric method according to ISO 2917:1999. Duplicate pH values were taken for each sample at each timepoint[1].

3.4.2 Total volatile basic nitrogen (TVB-N)

Total volatile basic nitrogen (TVB-N) assessment was performed according to the Egyptian Standard method of analysis and testing for meat and meat products part: 9 determination of total volatile nitrogen (Egyptian Organisation for Standards & Quality, 2006) which is equivalent to the FAO 1986. Briefly, a 10 g sample of raw meat was combined with 300 mL of Milli-Q water, 2 g of magnesium oxide and anti-bumping granules and boiled. A 100 mL volume of distillate was collected in a flask containing 25 mL of 2 % boric acid and indicator solution. The distillate was titrated with sulfuric acid (0.1 N). The process was repeated with distilled water in place of distillate to obtain a blank control. TVB-N was calculated as mg/100 g by subtracting the sample value from the blank and multiplying by the molecular weight of Nitrogen (M.W. 14).

3.4.3 Thiobarbituric acid (TBARS)

Lipid stability was assessed using a thiobarbituric acid reactive substances (TBARS) assay[2]. The assay was performed following Egyptian Standard No, 63-10 / 2006 (Egyptian Organisation for Standards & Quality, 2006b). Briefly, a 10 g sample of minced, raw meat was macerated with 50 mL water for 2 min. The resulting mixture was transferred to a distillation flask, using 47.5 mL water for rinsing. Following this, 2.5 mL of 4N HCl was added to the mixture to give a final pH of 1.5. Antifoam and glass beads were added to the flask and the mixture was distilled at a rate so that 50 mL of distillate was collected in 10 min from the time boiling commenced. Following this, 5 mL of distillate was combined with 5 mL of Thiobarbituric Acid Reagent in a glass stopper tube. The tube was then placed in boiling water for 35 min with shaking. The process was repeated to create a blank with 5 mL of water used in place of distillate. The sample and blank control were cooled, and the absorbance was measured against the blank at 538 nm. TBARS were calculated as mg

[1]For week 0 samples, lipid stability was determined by the thiobarbituric acid reactive substances (TBARS) assay as per Witte et al (1970), with modifications as detailed in MS2.

[2]For week 0 samples, pH was determined using the method detailed in MS2.

malonaldehyde per kg sample using the following equation: 7.8xA where A is the absorbance of the sample vs blank.

3.4.4 Drip loss (drip percent)

Following visual and odour assessment, the drip from each sample was collected and the following weights recorded: (i) weight of intact pack prior to opening, (ii) weight of samples excised for microbiological analysis, (iii) dry weight of primals after they had been patted dry with paper towel and (iv) the weight of vacuum bags after they had been washed and dried.

The drip loss was calculated on a weight loss basis and expressed as a percentage of the initial weight of the samples as follows:

The weight (wt) of drip was calculated using the following equation:

wt of drip = initial wt of pack – (wt of dry cut + wt of micro sample + wt of dry bag)

The percent (%) of drip was calculated using the following equation:

% drip = wt of drip/(initial wt of pack – wt of dry bag) X 100

3.5 Consumer acceptance

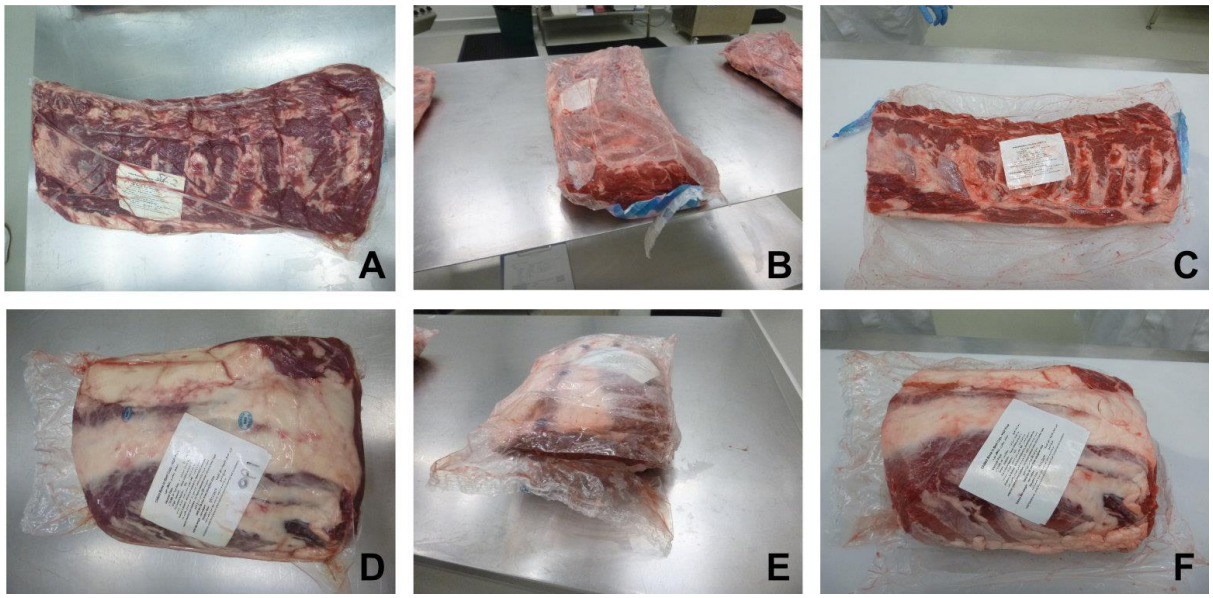
3.5.1 Sensory (appearance and odour)

Striploin and OP ribs were assessed by an informal 8-person panel (Australia) and 6-person panel (Egypt) for (i) vacuum-pack integrity (ii) intact pack meat colour, (iii) odour on opening the pack (confinement odour), (iv) meat colour after 30 min exposure to air and (v) odour after 30 min exposure to air (Figure 4.). Panelists were asked to assess vacuum-packs in a random order using a 9-point scale (Table 3 and Appendix 8.1). Packs were assessed from 0 to 8 for vacuum-pack integrity (no vacuum, probable leaker to complete vacuum, tight pack adhesion), meat colour (severe discolouration to very fresh, no discolouration) and meat odour (extreme off odour to fresh, no off/confinement odour).

Table 3. Visual and odour evaluation criteria.

Attribute – score plus comment		
Vacuum	**Appearance**	**Odour**
8 = complete vacuum, tight package adhesion 6 = good vacuum 4 = moderate vacuum 2 = poor vacuum 0 = no vacuum, probable leaker	8 = very fresh, no discolouration 6 = fresh, slight discolouration 4 = good, acceptable 2 = poor 0 = severe discolouration	8 = fresh, no off / confinement odour 6 = slight confinement / off odour 4 = typical confinement odour 2 = strong confinement / off odour 0 = extreme off odour

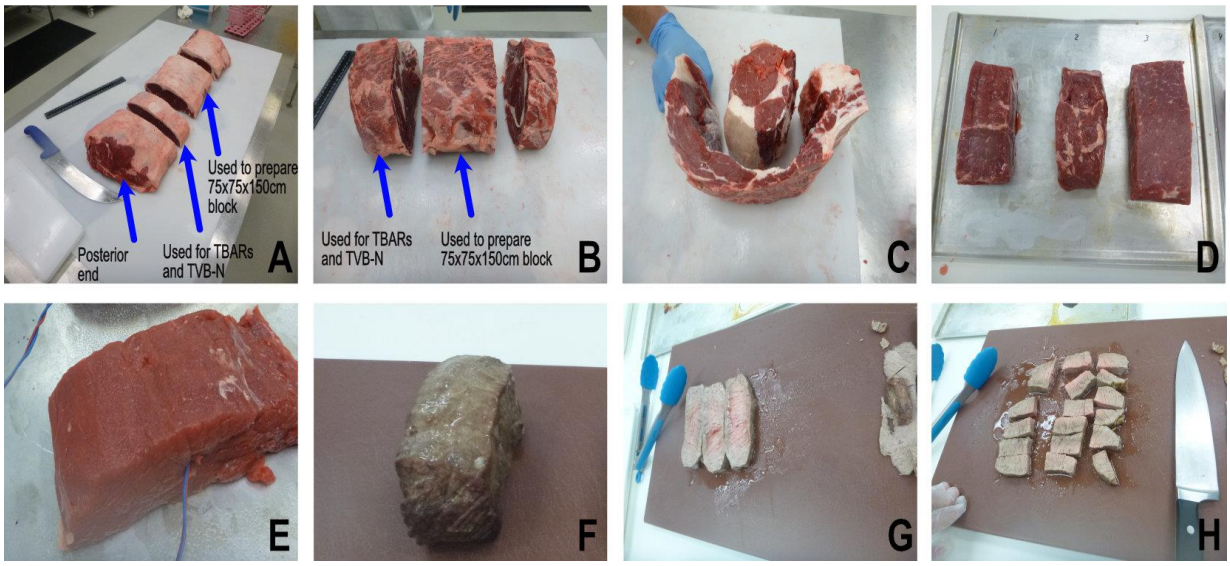
Figure 4. Preparation of samples for visual and olfactory analysis. Intact bags; striploin (A) and OP rib (D), on opening for blooming; striploin (B) and OP rib (E) and after 30 min exposure to air; striploin (C) and OP rib (F).



3.5.2 Sensory (eating quality)

Following visual and odour assessment, meat samples were trimmed of all fat and epimysium and a block measuring 75 × 75 × 150 mm was cut, vacuum-packed and placed at -1 °C for sensory assessment the following day (Figure 5.). Striploin (n=3) and OP rib (n=3) blocks of meat were removed from vacuum-packs and placed in groups of three onto two separate trays. Blocks of meat were fitted with a thermocouple inserted in their geometric centre and placed in a preheated oven (preheated to 160 °C) for roasting. The oven temperature was maintained at 160 °C and temperature probes were closely monitored throughout the cooking period. Each roast was removed from the oven when an internal temperature of 65 °C was reached. Roasts were then transferred to a cutting board, covered in foil and allowed to rest for 5 minutes before removing the facing slice from each end. The remaining portion was cut into 10 mm slices. Each slice was cut in half and then in thirds, prior to placing into covered foil trays for serving. A 6-member (Egypt) or 8-member (Australia) panel of assessors participated in the sensory analysis. Panelists were asked to consume a minimum of one to two mouthfuls of each sample, in random order, and assess them for tenderness (not tender to very tender), juiciness (not juicy to very juicy), flavour liking (dislike extremely to like extremely) and overall liking (dislike extremely to like extremely) using a 100 mm line scale on a printed paper ballot (MSA evaluation sheet, Appendix 8.2). The quality of each product was also rated, from unsatisfactory, good everyday, better than everyday or premium quality. Quality metrics were converted to numeric values increasing by values of 1 from unsatisfactory (1) to premium quality (4). Prior to assessment at CSIRO, a risk assessment for foods for human consumption was performed. Ethics approval was also obtained from CSIROs Health and Medical Human Research Ethics Committee (Proposal 2019_99_LR “Sensory testing of export chilled beef”) for sensory trials that occurred at CSIRO.

Figure 5. Preparation of striploin (A), OP rib (B, C) blocks for roasting (D, E), roast (F) and sample preparation (G, H) for sensory assessment.



4. Results

4.1 Temperature log history

Carton temperatures were measured throughout each leg of the journey from packing in Brisbane through to arrival in Cairo, Egypt (Table 4 and Figure 6). Following vacuum-packing, primals were placed into cartons and transferred to the processor's IBEX meat chilling system for rapid cooling. At this point carton temperatures dropped to between -1 ˚C and -3 ˚C and remained in that range for ~24 h. Following rapid cooling, cartons were transferred to the processor's cold store facility, where they remained between 0 ˚C and -1 ˚C for 7 days until load out on 06 Dec 19. Temperature profiles increased slightly at load out and gradually increased throughout each subsequent leg of the journey but remained below 5 °C at all points during transit from Brisbane to Cairo. A single carton containing temperature logger A211159 was unintentionally left at Gourmet Egypt (GE) during transit from GE to the Animal Health Research Institute. This carton exceeded 5 °C for 2 h and briefly peaked at 22 °C. As a slight reduction in shelf life was expected, a decision was made to test the product from this carton early in the shelf life study, during a period in which the product was not expected to show signs of deterioration.

On arrival at the Animal Health Research Institute (AHRI) in Egypt, cartons were transferred to a chiller for long term storage at -1 °C. Cartons were spaced throughout the chiller in the configuration shown in Figure 7. Overall, carton temperatures remained between 0 and -1 °C for most of the storage period with minimal temperature deviation recorded between cartons, regardless of carton location in the chiller. No temperature recordings were obtained for a brief window that occurred immediately prior to day 98 (week 14) sampling. This was the result of a fully discharged battery in temperature logger T00675. The logger was replaced with a similar data logger (T41419), used to record the temperature for the remainder of the trial. Assessment of microbiological data for the timepoint T4 (week 14) product were in the expected range, suggesting that temperatures likely remained in the desired range during the gap in recordings.

Table 4. Temperature history from Brisbane to Cairo

Week	Day	Trip code	Date	Time	Trip description
0	0	packed	26/11/2019	15:33	primals collected and packed into cartons at an Australian processor
0	0	tIBEX	26/11/2019	16:00	transferred to the processors meat chilling
0	**0**	**T0**	**26/11/2019**	**-**	**Week 0 testing**
0	2	tCS	28/11/2019	16:00	transferred to the processors cold store for storage at -1 °C until load out.
2	10	dKPC	06/12/2019	17:27	depart processor
2	10	dBNE	06/12/2019	23:45	departs Brisbane International Airport
2	11	aDXB	07/12/2019	13:49	arrive at Dubai International Airport
2	12	dDXB	08/12/2019	15:56	depart at Dubai International Airport
2	12	aCAI	08/12/2019	19:57	arrive at Cairo International Airport
2	13	aGE	09/12/2019	06:49	arrive at Gourmet Egypt
2	13	aLAB	09/12/2019	21:10	arrive at AHRI in Cairo
2	**15**	**T2**	**11/12/2019**	**-**	**Week 2 testing**
8	**56**	**T3**	**21/01/2020**	**-**	**Week 8 testing**
14	**98**	**T4**	**03/03/2020**	**-**	**Week 14 testing**
16	**112**	**T5**	**17/03/2020**	**-**	**Week 16 testing**
17	**119**	**T6**	**24/03/2020**	**-**	**Week 17 testing**
18	**126**	**T7**	**31/03/2020**	**-**	**Week 18 testing**
19	**133**	**T8**	**07/04/2020**	**-**	**Week 19 testing**

Figure 6. Temperature logger recordings throughout trial transport and storage. A. temperature fluctuation from sample collection in Brisbane to sample receipt in Cairo, Egypt and B. temperature fluctuation during controlled cold storage at the Animal Health Research Institute (AHRI), Cairo. A combination of 30, 90- and 180-day data loggers (KF1, JT1, KZ1, T00675, A21849, A21159, A21850, A21425, A21823, T41419) were used throughout the trial. Data loggers were packed into 5 boxes of striploin and 4 boxes of OP ribs which on arrival to AHRI lab were positioned at different locations within the chiller (Figure 7). Trip codes represent each of the significant journey legs from packing and time zero testing (pack & T0) through to final testing (T8) are detailed in Table 4.

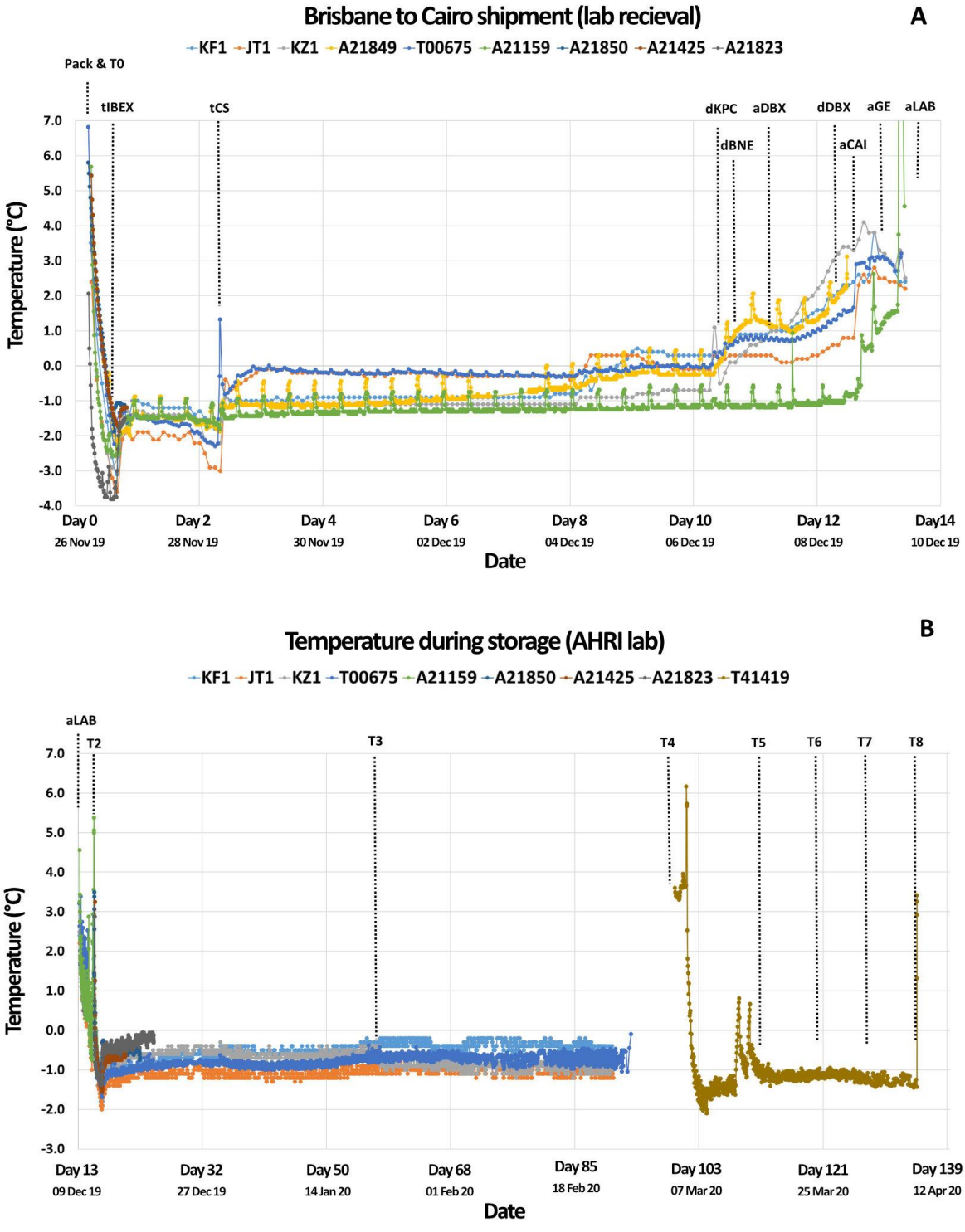
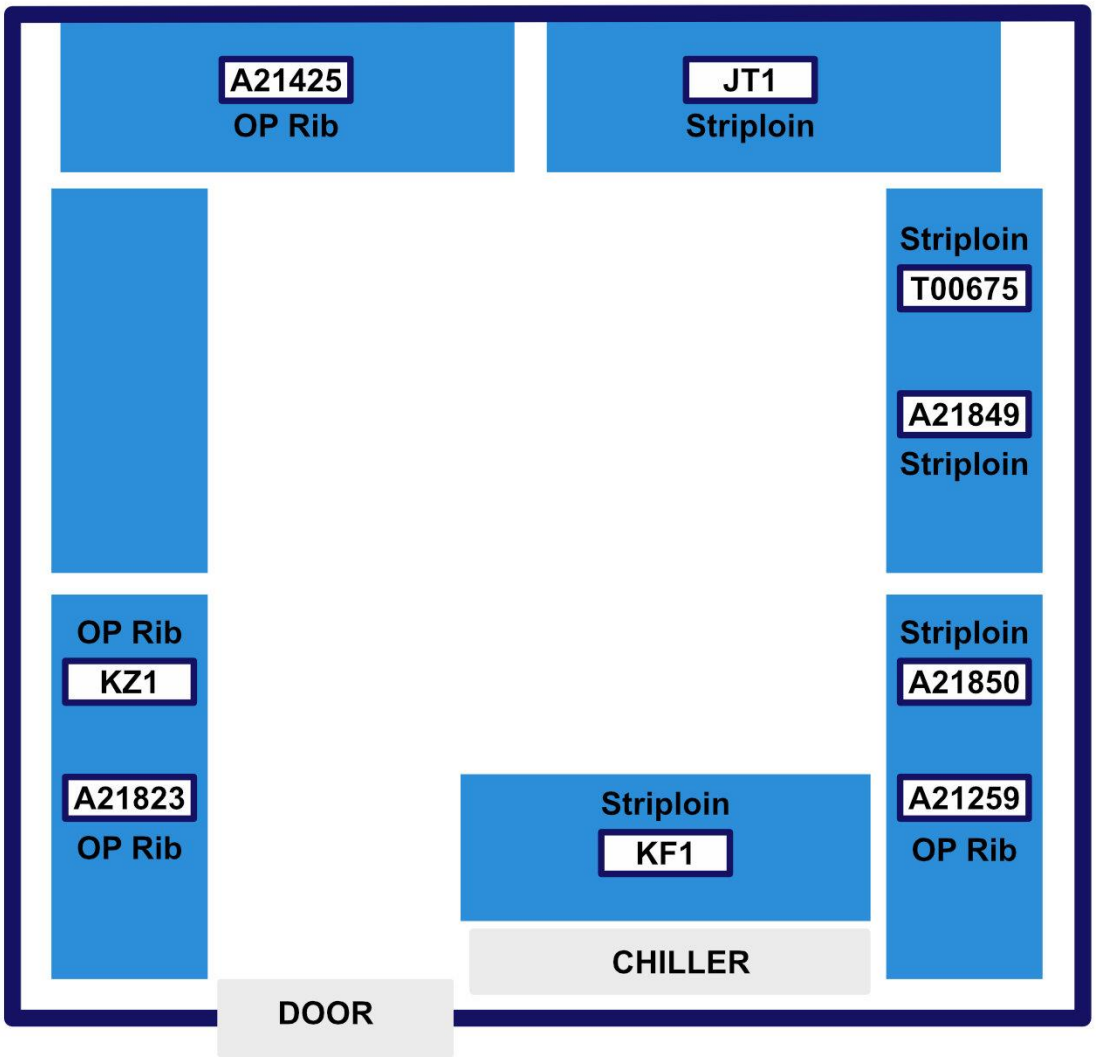


Figure 7. Egypt chiller layout and positioning of cartons containing temperature data loggers. Data logger codes details are provided in Table 1.



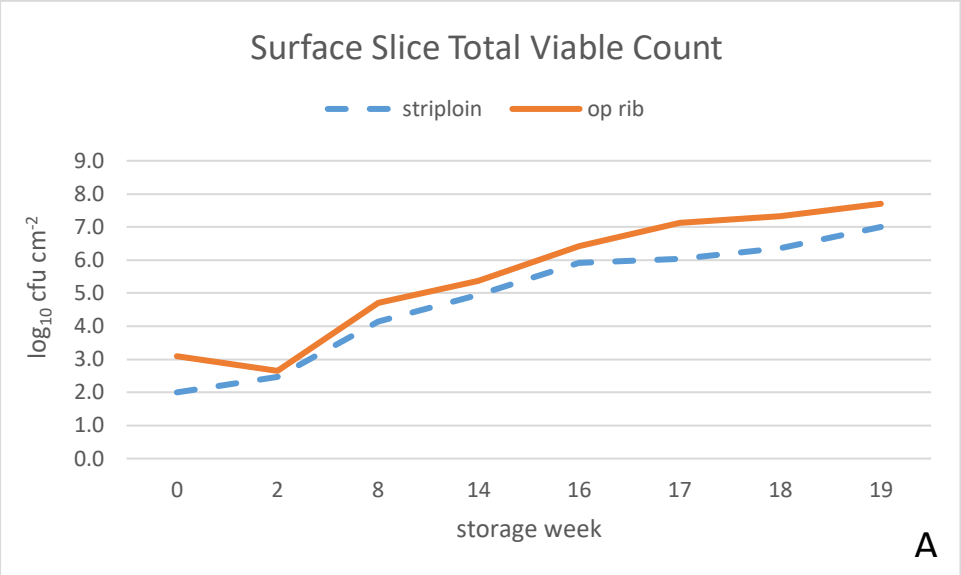
4.2 Microbiology

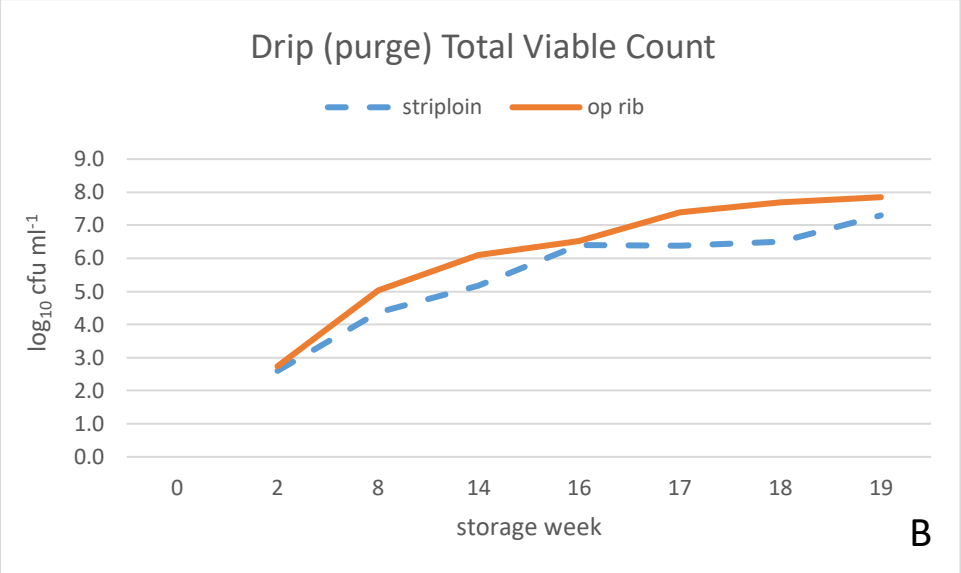
Mean total viable counts (TVC) are shown in Figure 8. The initial mean TVC on the surface of striploin primals was consistent with values reported in previous RDC/CSIRO funded shelf life projects (Australian Meat Processor Corporation, 2017) and is within acceptable limits. The TVC for OP ribs was ~1 $\log_{10}$ cfu cm^{-2} higher than striploin counts in all three replicates but was still considered to be within acceptable limits. Based on initial TVC, striploins and OP ribs were deemed suitable for inclusion in the trial and with management of the cold supply chain were expected to achieve extended shelf life.

The TVC increased gradually for both primal and sample types. Surface tissue mean counts of 2.0 $\log_{10}$ cfu cm^{-2} for striploin and 3.1 $\log_{10}$ cfu cm^{-2} for OP ribs were recorded for week 0 samples. Surface tissue counts remained at or below the Egyptian Standard limit of 6 $\log_{10}$ cfu cm^{-2} until 119 days (17 weeks) for striploin and 98 days (week 14) for OP ribs (Appendix 8.3). Both drip and surface tissue samples displayed similar TVC trends when plotted, though drip TVC were consistently higher

than surface tissue samples. No comment can be made regarding shelf life limits for drip TVC as limits are not stipulated in the Egyptian Standards.

Figure 8. Mean total viable count of A. surface meat (log_{10} cfu cm^{-2}) and B. drip (log_{10} cfu mL^{-1}) samples from vacuum-packed striploin and Oven Prepared rib. Note: no drip was recovered on week 0.





4.3 Estimated shelf life

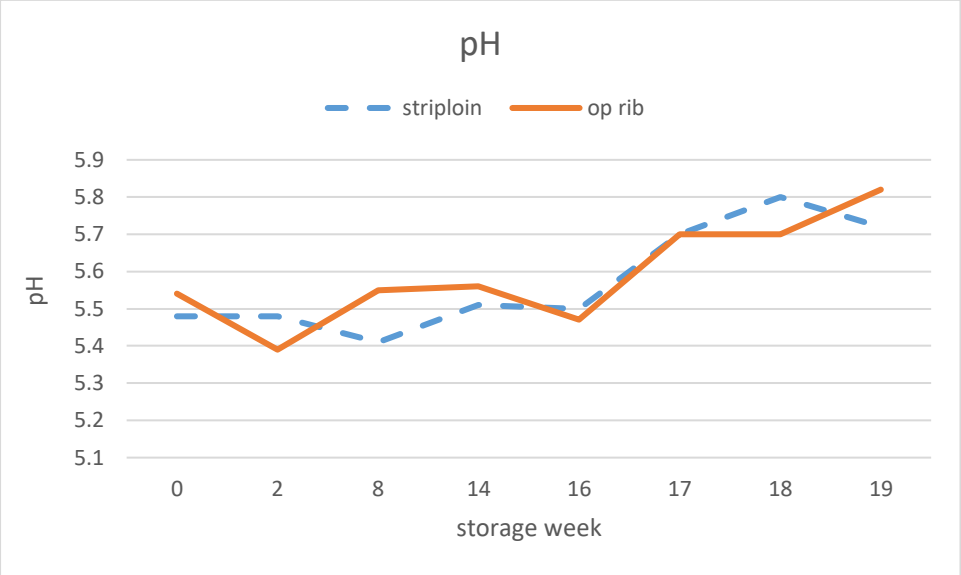
Initial microbiology counts and temperature log data were used to predict the shelf life of the product using a shelf life predictive model for beef (version 5; MLA 2017). The model predicts remaining shelf life of product based on the initial TVC and the time-temperature history of the product tested. At the last tested timepoint (133 days/week 19), striploin primals were predicted to have a remaining shelf life of 28 days when stored at 1 °C and 15 days when stored at -0.5 °C (Appendix 8.4). The OP ribs were predicted to have a slightly shorter remaining shelf life of 12 days when stored at 1 °C and 6 days when stored at -0.5 °C (Appendix 8.5). As only two criteria are used in the shelf life model, the shorter predicted remaining shelf life of OP ribs can be wholly attributed to

the 10-fold higher initial TVC observed in OP ribs (3.1 $\log_{10}$ cfu cm^{-2}) compared to striploin (2.0 $\log_{10}$ cfu cm^{-2}).

4.4 Physical and chemical characteristics

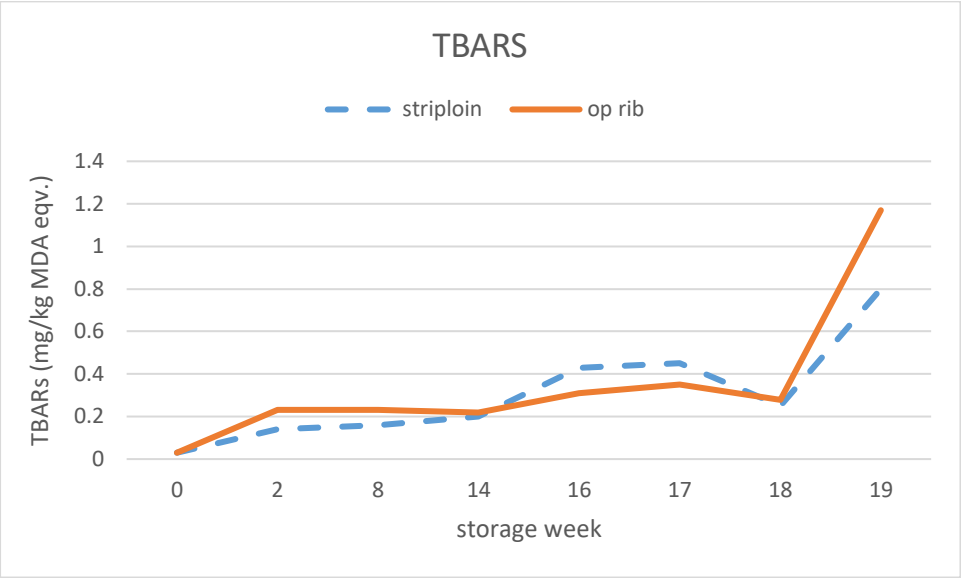
Initial (week 0) pH values for both primals were within the range that is acceptable for MSA grade carcases (Meat Standards Australia - MSA08). The pH values fluctuated between 5.4 and 5.6 until 16 weeks before gradually increasing to 5.7-5.8 by 133 days (19 weeks) (**Figure *9***). Values remained within Egyptian Standard Specifications (Egyptian Organisation for Standards & Quality, 2013) limits (5.4-5.8) throughout the duration of the trial.

Figure 9. Mean pH values for vacuum-packed chilled striploin and Oven Prepared rib stored to 19 weeks.



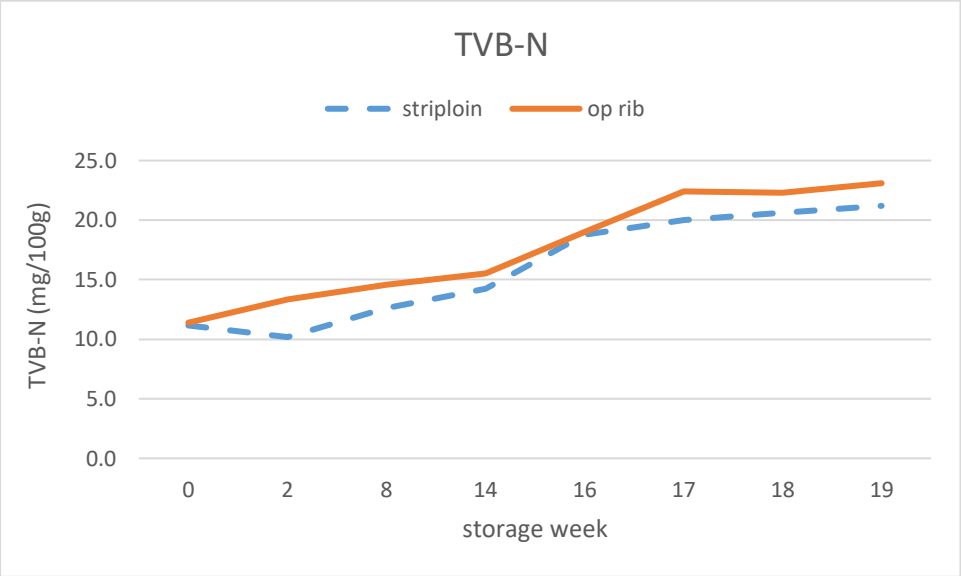
Initial lipid oxidation scores were low (below 0.1 mg/kg MDA eqv.) in all samples, which is consistent with previous shelf life trials of VP beef (Australian Meat Processor Corporation, 2017). TBARS increased gradually over the course of the trial but remained within the permissible limit (≤0.9 mg/kg MDA eqv.) of the Egyptian Standard (Egyptian Organisation for Standards & Quality, 2013) until 133 days (19 weeks) of storage for striploin and 126 days (18 weeks) of storage for OP ribs (**Error! Reference source not found.**).

Figure 10. Mean thiobarbituric acid reactive substances values of vacuum-packed chilled striploin and OP rib stored for 19 weeks.



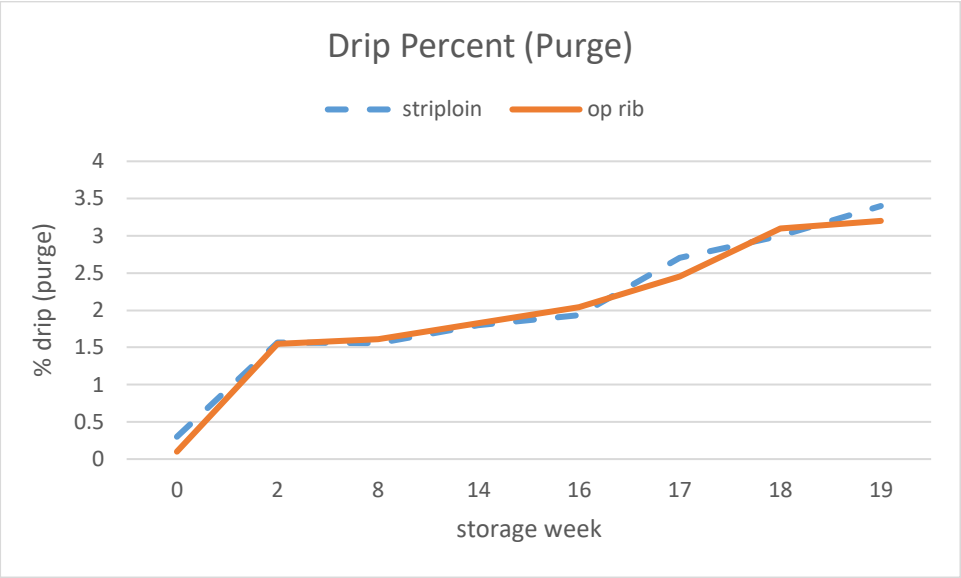
Mean Volatile Nitrogen compound values increased gradually in both primals throughout storage (**Figure *11***). Mean striploin values were consistently lower than OP rib values, but both followed similar trends. The TVB-N values remained within the Egyptian Standard Specifications (Egyptian Organisation for Standards & Quality, 2013) limit (20 mg/100g) until 112 days (16 weeks) of storage for OP ribs and 119 days (17 weeks) of storage for striploin samples.

Figure 11. Mean total volatile basic nitrogen (mg/100 g) values for vacuum-packed chilled striploin and OP rib stored for up to 19 weeks.



The initial (week 0) drip percent was negligible (0.1-0.3 %) and within the expected range (0.1 to 1 %) for primals tested shortly after vacuum-packaging (Commonwealth Scientific and Industrial Research Organisation, 2002). The drip percent increased gradually for striploin and OP rib, with similar trends recorded for both primals (Figure 12). The mean drip percent was within the permissible limit of ≤2 % (weight/weight) until 112 days (16 weeks) storage for striploin and 98 days (14 weeks) of storage for OP ribs.

Figure 12. Mean drip percent of vacuum-packed chilled striploin and OP rib stored for up to 19 weeks.



4.5 Consumer acceptance

4.5.1 Sensory (appearance and odour)

Samples were assessed informally by a 6-person panel (Egypt) or an 8-person panel (Australia) for vacuum integrity and appearance pre- and post-bloom (after 30 min exposure to air). Panel participants were asked to rate meat attributes using a 9-point scale according to the criteria listed in Table 3. A score of 4 or greater was deemed acceptable for vacuum, appearance and odour.

Overall, mean appearance (Figure 13) and odour (Figure 14) for pre- and post-bloom packs and vacuum integrity scores were high across all samples tested and for the majority of the storage trial rated well above the acceptable threshold of ≥4 . Striploin remained at or above 4 for appearance and odour until 19 weeks of storage while OP ribs remained acceptable until 18 weeks of storage. Appearance and odour scores progressively declined for both primals overtime.

Figure 13. Mean meat appearance scores of unopened (in-pack) and post-bloom (after 30 min exposure to air) vacuum-packed striploin and OP rib primals.

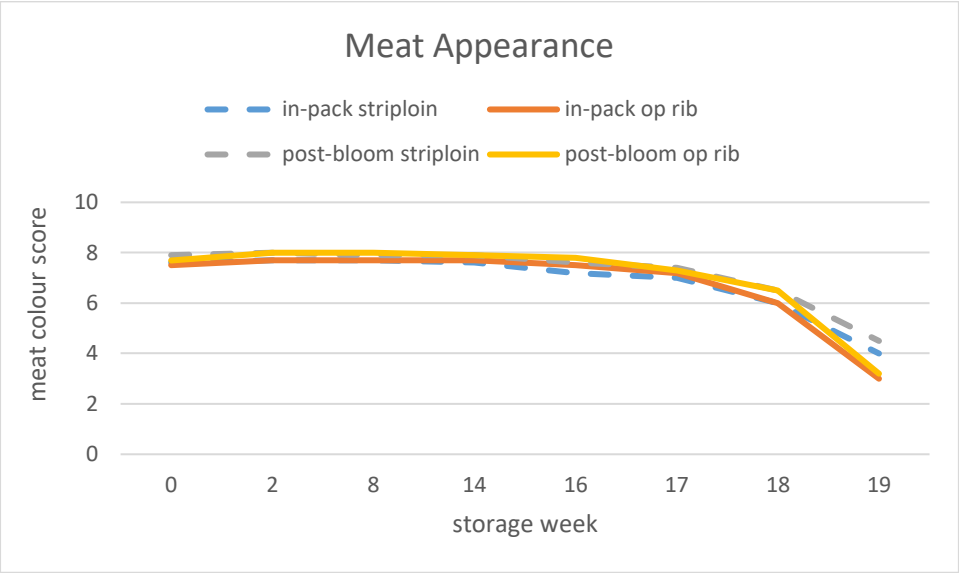
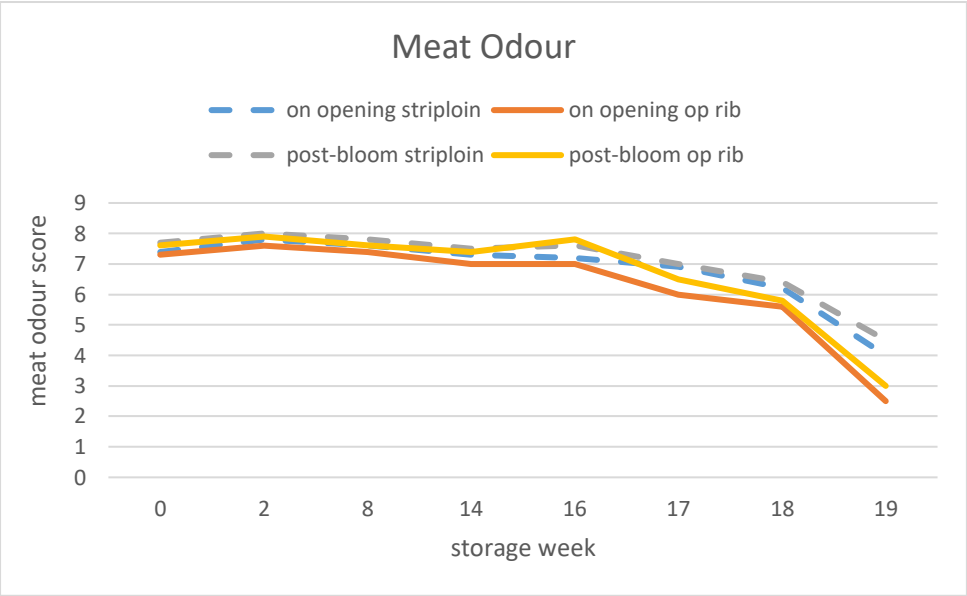
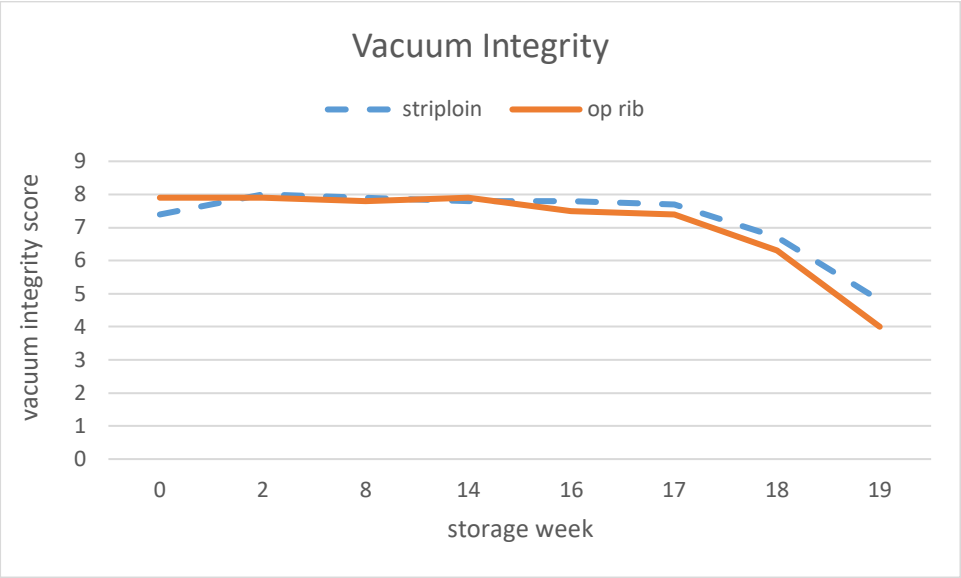


Figure 14. Mean meat odour scores on opening and post-bloom (after 30 min exposure to air) for vacuum-packed striploin and OP rib primals.



Vacuum integrity (**Figure *15***) progressively declined for both primals overtime; however, both striploin and OP rib primals maintained acceptable vacuums throughout the trial until the final sampling week (week 19).

Figure 15. Mean vacuum integrity scores for vacuum-packed chilled striploin and OP rib stored up to 19 weeks.



4.5.2 Sensory (eating quality)

Roast beef samples were prepared for striploin and OP rib primals and informally assessed by a 6-member (Egypt) and 8-member (Australia) panel using a 100-point scale. Scores above 50 for any criteria – tenderness (**Figure *16***), juiciness (Figure 17), liking of flavour (Figure 18) and overall liking (Figure 19) were considered acceptable. Samples were tested for eating quality until week 18. Due to a combination of lower relative scores at week 19 for product appearance, odour and vacuum integrity, a decision was made not to proceed with sensory assessment of either product type at this timepoint.

Trends for striploin and OP rib samples were similar across each tested parameter. At week 0, both primals scored low for tenderness, which is to be expected for samples that have not been aged for the minimum period (1-2 weeks) required to achieve acceptable tenderisation. Average eating quality scores across all 5 criteria were higher at week 0 for OP rib than striploin samples. The OP ribs were considered acceptable for juiciness and liking of flavour but unacceptable for overall liking and quality. Striploin samples were slightly below acceptable for juiciness and liking of flavour and well below for overall liking and quality. The lack of ageing of the product is likely to be an important factor contributing to the low overall scores for product tested at week 0.

For the remaining weeks (2-18), all sensory criteria were scored above the acceptable threshold of 50. Tenderness scores remained high for most of the trial with mean scores at or above 85 for both primals until 119 days (17 weeks) of storage. At 126 days (18 weeks), scores began to decline but remained above the acceptable cut-off of 50 for both primals. Juiciness scores gradually declined from day 14 to 112 (week 2 to 16) and then displayed a more pronounced deterioration from day 112 to 126 (week 16 to 18) but remained above the acceptable cut-off of 50 at all timepoints. Liking of flavour and overall liking followed similar trends, with scores remaining consistently high between day 14 and 98 (week 2 and 14) and then showing a gradual decline to between 60 and 65 by day 126 (week 18).

Figure 16. Mean tenderness scores for vacuum-packed chilled striploin and OP rib stored up to 18 weeks.

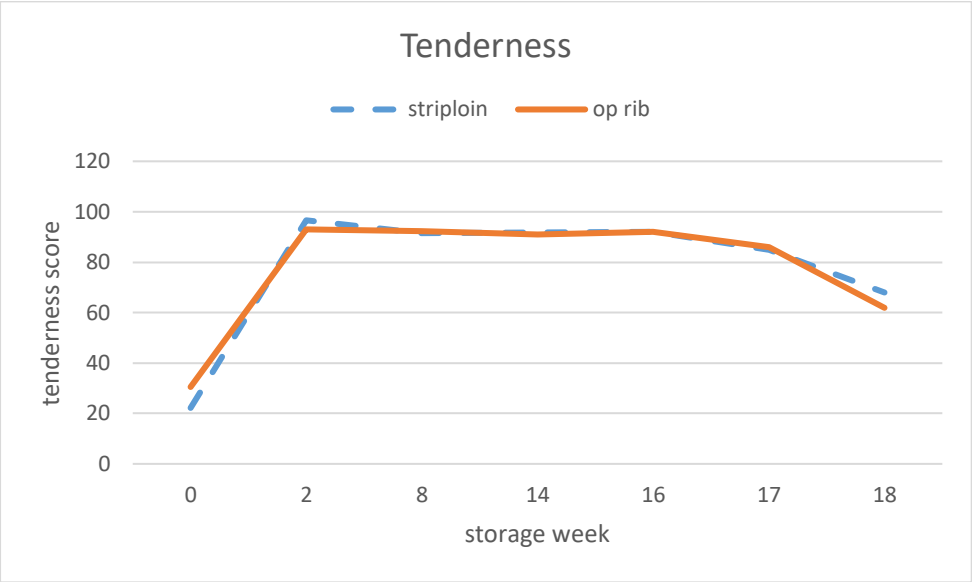


Figure 17. Mean juiciness scores for vacuum-packed chilled striploin and OP rib stored up to 18 weeks.

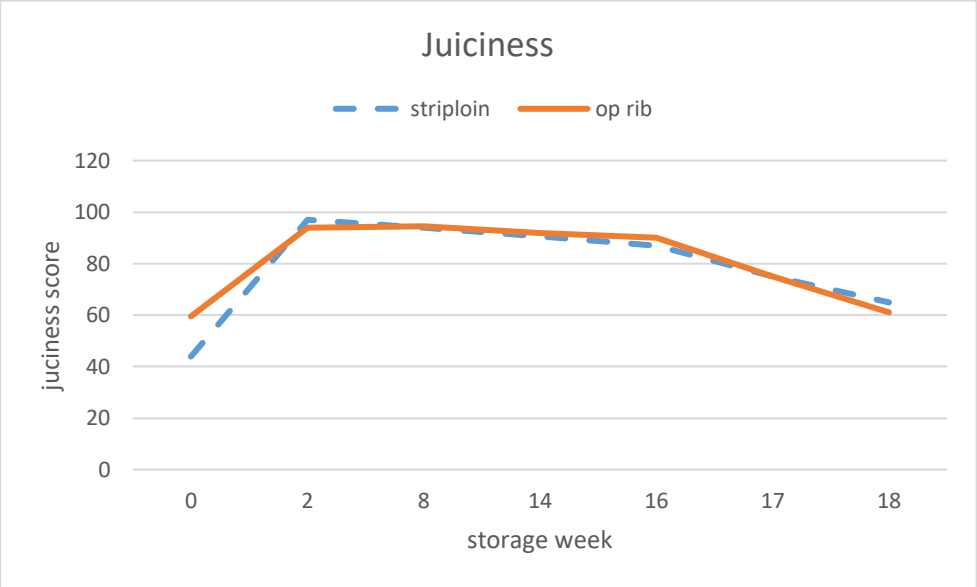


Figure 18. Mean liking of flavour scores for vacuum-packed chilled striploin and OP rib stored up to 18 weeks.

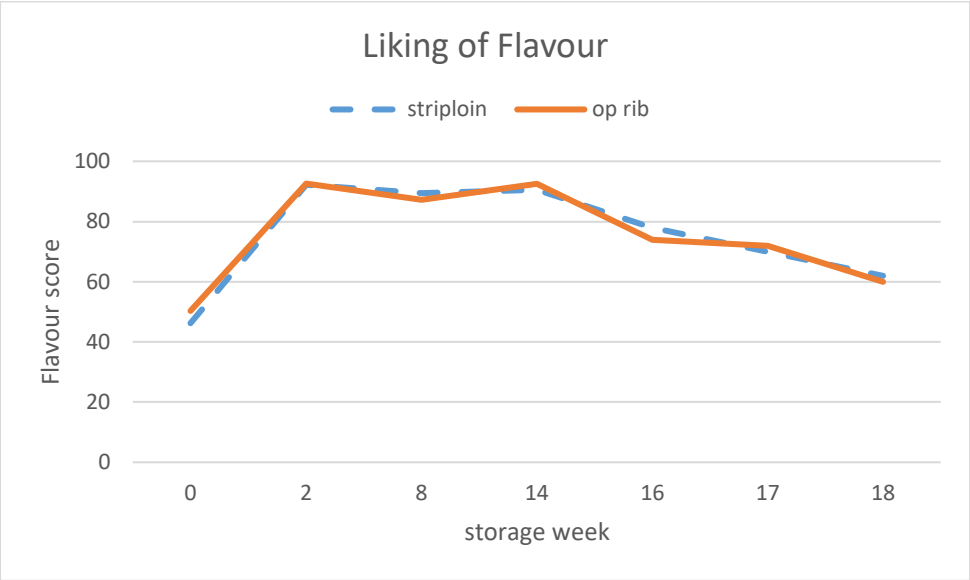
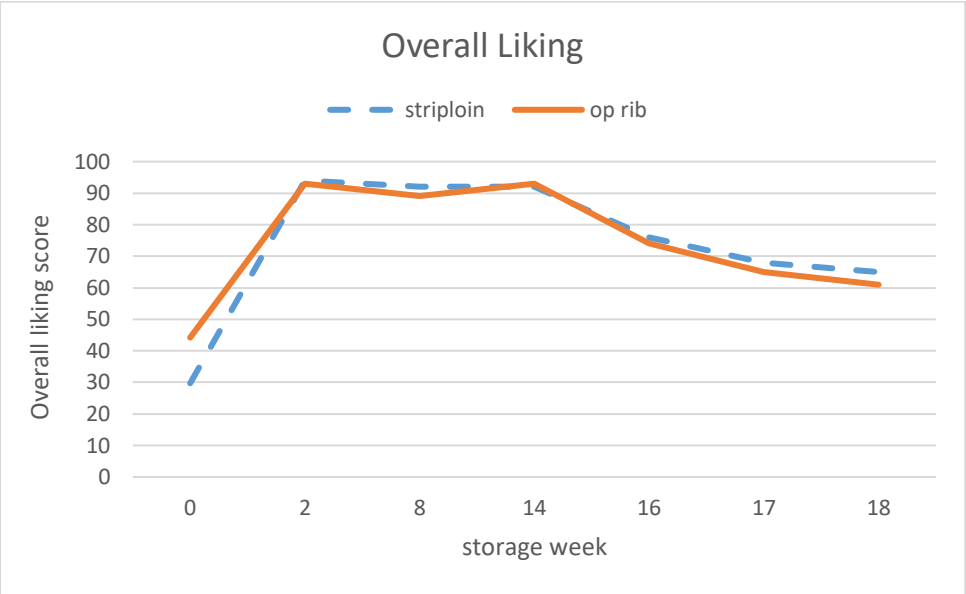
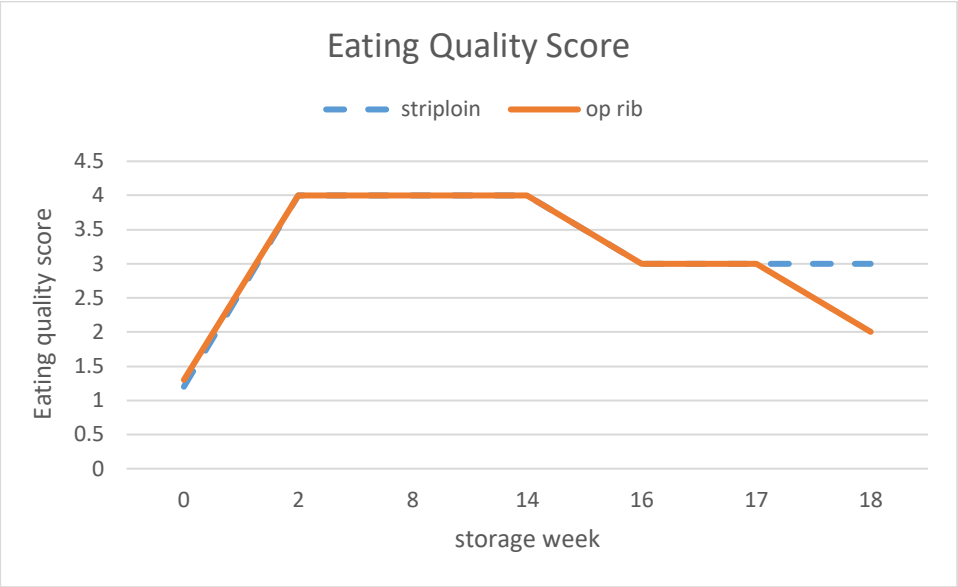


Figure 19. Mean overall liking scores for vacuum-packed chilled striploin and OP rib stored up to 18 weeks.



The panel also assessed samples for a 5th attribute (quality) which was scored as unsatisfactory (1), good everyday quality (2), better than everyday quality (3) and premium quality (4). Quality scores of two or greater were considered acceptable (**Figure *20***). Both primals were rated as premium quality from day 14 to 98 (week 2 to 14), striploins were rated as better than everyday quality from day 112 to 126 (week 16 to 18) and OP ribs were scored as better than everyday quality from day 112 to 119 (week 16 to 17) and good everyday quality for day 126 (week 18).

Figure 20. Mean eating quality scores for vacuum-packed chilled striploin and OP rib stored up to 19 weeks.



5. Conclusion

Results of this study provide "real world" evidence to support the Australian industry claim that VP beef have a practical storage life of 140 days at 0 to -1 °C. Australian beef producers have excellent production and hygiene practices that allow the production of VP beef with properties required for achieving extended shelf life. These properties include low meat pH, low initial bacterial loads, good vacuum seals with low oxygen transmission through bags and controlled storage at 0 to -1 °C. The Australian industry consistently produces product that meet these specifications that result in superior shelf life attributes of Australian beef and that give industry an important global advantage. The VP primals used in this trial displayed the desired properties that are typical of the broader Australian industry and were therefore deemed suitable for inclusion in the study.

Good temperature control throughout the cold supply chain is essential for maximising product shelf life. To maximise shelf life, VP beef should be stored at between 0 and -1 °C, with minimal deviation from the ideal temperature. This study shows that the cold supply chain from the Australian processor to AHRI in Cairo was adequately controlled to achieve extended shelf life of vacuum-packed beef (up to 126-days). Although deviations from the ideal temperature (0 to -1 °C) occurred when the product was in transit, these deviations were small (~5 °C) and of short duration (2 h), resulting in minimal impact on the remaining shelf life of the product. Supporting this, shelf life modelling predicted that primals would achieve greater than 140-days, which is consistent with industry experience and past shelf life studies conducted in Australia. Egyptian Standard limits are based on a storage temperature of 0 to 2 °C which is much higher than the recommended storage temperature of 0 to -1 °C. It is estimated that for every 1 °C drop in temperature, shelf life increases by approximately 30 % (Meat & Livestock Australia, 2020). As a result, storage of product according to the Egyptian Standard would result in a much shorter shelf life than would otherwise be achieved at lower storage temperatures.

Sensory properties (appearance, odour and eating quality) were used to determine the acceptability of beef for human consumption. Both bone-in and boneless primals had acceptable sensory properties until 126 days (18 weeks) of cold storage, which was shorter than shelf life model

predictions. The discrepancy between the predicted and observed shelf life may, in part, be explained by the approach that was used for sensory assessment. Due to a desire to test fresh product, sensory assessment was conducted in real-time at each timepoint and therefore the sensory panel in this study had an expectation of product deterioration as the shelf life trial progressed. Similar past shelf life studies have frozen product at each timepoint for random sensory assessment of all products simultaneously at the end of the project. By testing product in real-time, the panel would be expecting progressive deterioration of product and therefore may have been more critical of product attributes at later timepoints. Alternatively, international consumer preferences and acceptability thresholds may be different to Australian consumer thresholds, the latter of which formed the basis of the shelf life model.

Egyptian Standards specify shelf life criteria and limits around microbiological counts, the volume of fluid (drip) in a pack and the concentration of certain chemicals such as total volatile nitrogen compounds. VP primals remained within Egyptian Standard limits for the majority of the period of sensory acceptability. However, a number of quality indicators including TVB-N, TVC and drip percent exceeded Egyptian Standard limits at 126 days (18 weeks) when the product was otherwise considered organoleptically acceptable. The results of this study suggest that Egyptian Standard limits for these quality measures were poor predictors of the sensory acceptability of Australian beef.

5.1 Key findings

Australian OP ribs and striploin were shown to have acceptable appearance and sensory properties until 126 days (18 weeks) of cold storage and the product remained within Egyptian Standard quality criteria limits for the majority of the period of sensory acceptability. A number of quality indicators exceeded allowable limits in product with acceptable sensory properties, which suggests that these limits may not be appropriate for Australian product and may need to be reviewed and revised as appropriate. A revision of the shelf life limit to 120 days (17 weeks) would be consistent with shelf life limits imposed by some countries in the Gulf region.

5.2 Benefits to industry

Increasing the shelf life of vacuum-packed meat in Egypt would provide many opportunities for businesses in Australia and Egypt. Industry would benefit from reduced freight costs in supply chains allowing businesses in Egypt to provide quality products at lower prices. Increased shelf life limits would provide opportunities in Egypt to develop food manufacturing (export) businesses, working in tandem to create new markets for Australian export establishments. Beef that remains fresh for longer durations will also reduce product wastage throughout the supply chain. The results provide further evidence to reinforce the superior shelf life attributes of Australian beef that give industry a global competitive advantage. Finally, the study contributes to the overall Australian beef industry objective to create new market opportunities or cost saving through reductions in technical barriers to trade of $250 million by 2030.

6. Future research and recommendations

- Future studies should consider the bias introduced when testing fresh product and consider freezing product for randomised sensory (organoleptic) assessment at the conclusion of the trial or assessing product by both methods (fresh and frozen).
- The findings suggest that the current Egyptian criteria for assessing the quality and shelf life limits of VP beef are unlikely to be appropriate for Australian product which has been shown in multiple studies to achieve extended shelf life of up to 140 days (20 weeks). On the basis of these findings and previously reported data, Egyptian shelf life criteria should be reviewed and revised as appropriate. The results of this trial should be used as a basis to pursue negotiations with relevant regulatory bodies in Egypt to increase the shelf life limits on bone-in and boneless vacuum-packed chilled beef primals. Future amendments to the Egyptian Standard should include a change in storage temperature from 0 to 2 °C to 0 to -1 °C, a critical component in achieving extended shelf life.
- A sheepmeat shelf life extension project should be considered to develop the scientific basis for extending shelf life limits to 90 days or beyond, which would be in-line with recent extensions made by the United Arab Emirates government.
- This study focussed on airfreight, however, temperature variations through sea freight could differ and therefore the sea freight supply chain from Australia to Egypt may need to be verified to confirm good cold supply chain management.
- Good temperature data modelling will give the Australian export industry a global advantage and shelf life models should continue to be refined and new models developed and validated for beef and lamb. Models should consider sensory preferences and product acceptability thresholds of consumers in international markets, which may differ from sensory preferences in Australia. Models should also consider differences in bone-in vs boneless product and the shelf life of product in other non-VP forms of packaging used by industry.
- More information on “real world” cold supply chain temperatures should be collected for major export markets to demonstrate integrity of cold supply chains to customers. Temperature data should be collected across all legs of the cold supply chain from packing through to retail storage in overseas markets.
- More work should be conducted to establish the shelf life of bone-in product, which is considered to be shorter than boneless products. If studies demonstrate that bone-in product has a shorter shelf life, further research should be undertaken to establish the reasons for the shorter shelf life of bone-in product. The increased potential for piercing of bags in bone-in cuts resulting in loss of vacuum is an important consideration for supply chain management and should be investigated for product where data is lacking.

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8. Appendix

8.1 Appearance and odour evaluation sheet

Date:

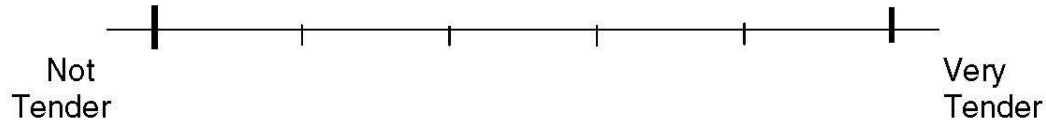
Sample number	**Attribute – score plus comments**					**Comments**
	Vacuum 8 = complete vacuum, tight package adhesion 6 = good vacuum 4 = moderate vacuum 2 = poor vacuum 0 = no vacuum, probable leaker	**Appearance** 8 = very fresh, no discolouration 6 = fresh, slight discolouration 4 = good, acceptable 2 = poor 0 = severe discolouration		**Odour** 8 = fresh, no off / confinement odour 6 = slight confinement / off odour 4 = typical confinement odour 2 = strong confinement / off odour 0 = extreme off odour		
		Intact pack	**After 30 minutes exposure to air**	**On opening**	**After 30 minutes exposure to air**	

Note: when assessing appearance, please observe for characteristics listed in the **TEST PARAMETERS and SUCCESS CRITERIA** table above.

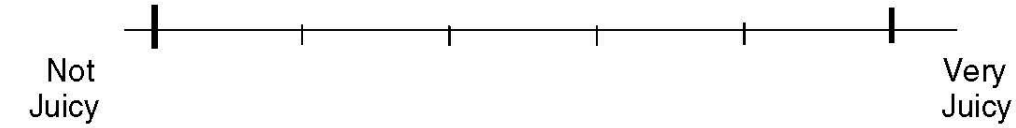
8.2 Sensory evaluation sheet

PRODUCT :

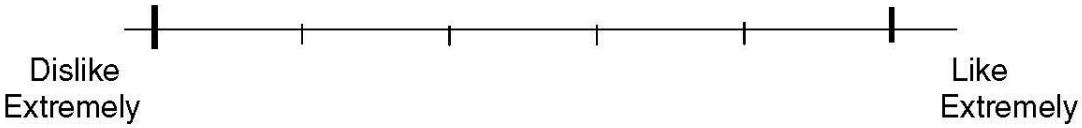
Tenderness



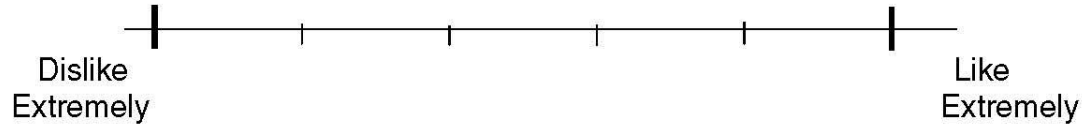
Juiciness



Liking of flavour



Overall Liking



Please tick ☑ one of the following to rate the quality of the beef sample you have just eaten

Choose **one** only (you must make a choice).

Unsatisfactory	☐
Good everyday quality	☐
Better than everyday quality	☐
Premium quality	☐

8.3 Mean physical, chemical, microbiological, appearance and sensory values for vacuum-packed chilled striploin and Oven Prepared rib stored for up to 19 weeks.

		storage week							
primal	**criteria**	**0**	**2**	**8**	**14**	**16**	**17**	**18**	**19**
OP rib									
	meat quality attributes								
	pH	5.5*	5.4	5.6	5.6	5.5	5.7	5.7	5.8
	TVB-N (mg/100 g)	11.4	13.4	14.6	15.6	19.0	22.4	22.3	23.1
	TBARS (mg/kg MDA eqv.)	0.03	0.23	0.23	0.22	0.31	0.35	0.28	1.17
	drip %	0.26	1.55	1.61	1.83	2.04	2.45	3.10	3.20
	microbiology								
	Total viable count log_{10} cfu cm^{-2} (muscle tissue)	3.1	2.7	4.7	5.4	6.4	7.1	7.3	7.7
	Total viable count log_{10} cfu mL^{-1} (drip)	-ǂ	2.7	5.0	6.1	6.5	7.4	7.7	7.9
	appearance								
	appearance (intact pack)	7.5	7.7	7.7	7.7	7.5	7.2	6	3
	appearance (after bloom) ǂ	7.7	8	8	7.9	7.8	7.3	6.5	3.2
	odour (on opening)	7.3	7.6	7.4	7	7.5	6	5.6	2.5
	odour (after bloom)	7.6	7.9	7.6	7.4	7.8	6.5	5.8	3
	vacuum	7.9	7.9	7.8	7.9	7.5	7.4	6.3	4
	sensory								
	tenderness	30.9	93	92.3	91	92	86	62	nt§
	juiciness	58.8	93.9	94.5	92	90	75	61	nt
	liking of flavour	61.9	92.6	87.2	92.5	74	72	60	nt
	overall liking	44.9	93	89	93	74	65	61	nt
	quality	1.3	4	4	4	3	3	2	nt
Striploin									
	meat quality attributes								
	pH	5.5	5.5	5.4	5.5	5.5	5.7	5.8	5.7
	TVB-N (mg/100 g)	11.2	10.2	12.6	14.2	18.8	20.0	20.6	21.2
	TBARS (mg/kg MDA eqv.)	0.03	0.14	0.16	0.2	0.43	0.45	0.25	0.8
	drip %	0.12	1.57	1.56	1.80	1.93	2.70	3.00	3.40
	microbiology								
	Total viable count log_{10} cfu cm^{-2} (muscle tissue)	2.0	2.5	4.2	5.0	5.9	6.0	6.4	7.0
	Total viable count log_{10} cfu mL^{-1} (drip)	-	2.6	4.4	5.2	6.4	6.4	6.5	7.3
	appearance								
	appearance (intact pack)	7.6	7.7	7.7	7.6	7.2	7	6	4
	appearance (after bloom)	7.9	8	7.9	7.9	7.6	7.4	6.5	4.5
	odour (on opening)	7.4	7.8	7.6	7.3	7.2	6.9	6.2	4
	odour (after bloom)	7.7	8	7.8	7.5	7.6	7	6.4	4.5
	vacuum	7.4	8	7.9	7.8	7.8	7.7	6.7	4.8
	sensory								
	tenderness	22.2	96.6	91.4	91.8	92	85	68	nt
	juiciness	43.9	97	93.6	90.6	87	75	65	nt
	liking of flavour	46.2	92.2	89.5	90.6	78	70	62	nt
	overall liking	29.7	94	92	92	76	68	65	nt
	quality	1.2	4	4	4	3	3	3	nt

*Cells shaded green have values that are within the acceptable limit of the Egyptian Standard or were deemed acceptable based on success criteria listed in Table 2.

[ŧ]Volume of drip was insufficient for total viable count assessment.

[‡]Primals were exposed to air for 30 min prior to testing.

[§]Not tested. Due to a combination of lower relative scores at week 19 for product appearance, odour and vacuum integrity, a decision was made not to proceed with sensory on either product type at this timepoint.

8.4 Estimated remaining shelf life of striploin after 19 weeks of cold storage (MLA shelf life model v5)

Journey Description: Egypt trial Completed

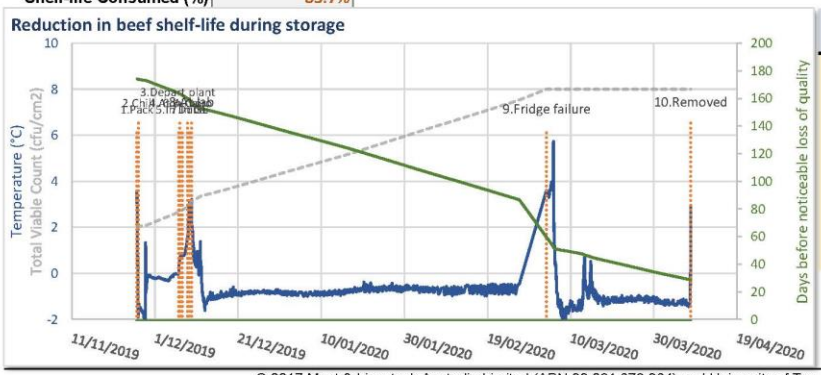
Logger summary	
Start Date/Time:	26/11/2019 16:33
End Date/Time:	7/04/2020 20:33
Recording Interval (min):	3.9 to 9382.3 min

Temperature Summary	
Average Temp:	-0.49 °C
Min Temp:	-2.28 °C
Max Temp:	5.73 °C

Shelf-life summary	
Storage Duration	133.17 days
Shelf-life Consumed	146.25 days
Shelf-life Consumed (%)	83.7%

Product: Beef	Bacterial numbers (TVC) (cfu)	(log cfu)
Initial	100	2.00
Increase	×1,000,000	6.00
Final	100,000,000	8.00

	Temperature	Expected Shelf-life, if temperature held constant	Estimated Shelf-life Remaining, actual temperature trace provided
Preferred	-0.50 °C	174 days	28 days
Expected (remaining storage)	1.00 °C		15 days
		Show Additional	no



Journey Information: Event Description	Date/Time	% Shelf-life Consumed
1.Pack	26/11/2019 15:33	0.0%
2.Chill	27/11/2019 0:35	0.2%
3.Depart plant	6/12/2019 17:27	5.8%
4.At Airport	6/12/2019 23:45	0.2%
5.In Dubai	7/12/2019 13:49	0.6%
6.In Cairo	8/12/2019 19:57	1.4%
7.In GE	9/12/2019 6:49	0.8%
8.At lab	9/12/2019 19:29	1.1%
9.Fridge failure	4/03/2020 4:14	55.8%
10.Removed	7/04/2020 20:30	17.8%

8.5 Estimated remaining shelf life of OP ribs after 19 weeks of cold storage (MLA shelf life model v5)

Journey Description: Egypt trial Completed

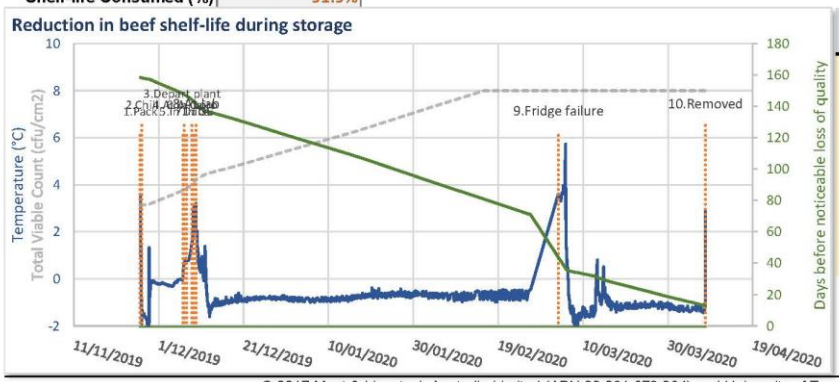
Logger summary	
Start Date/Time:	26/11/2019 16:33
End Date/Time:	7/04/2020 20:33
Recording Interval (min):	3.9 to 9382.3 min

Temperature Summary	
Average Temp:	-0.49 °C
Min Temp:	-2.28 °C
Max Temp:	5.73 °C

Shelf-life summary	
Storage Duration	133.17 days
Shelf-life Consumed	146.54 days
Shelf-life Consumed (%)	91.9%

Product: Beef	Bacterial numbers (TVC) (cfu)	(log cfu)
Initial	1258	3.10
Increase	×79,491	4.90
Final	100,000,000	8.00

	Temperature	Expected Shelf-life, if temperature held constant	Estimated Shelf-life Remaining, actual temperature trace provided
Preferred	-0.50 °C	159 days	12 days
Expected (remaining storage)	1.00 °C		6 days
		Show Additional	no



Journey Information: Event Description	Date/Time	% Shelf-life Consumed
1.Pack	26/11/2019 15:33	0.0%
2.Chill	27/11/2019 0:35	0.3%
3.Depart plant	6/12/2019 17:27	6.3%
4.At Airport	6/12/2019 23:45	0.2%
5.In Dubai	7/12/2019 13:49	0.6%
6.In Cairo	8/12/2019 19:57	1.5%
7.In GE	9/12/2019 6:49	0.9%
8.At lab	9/12/2019 19:29	1.2%
9.Fridge failure	4/03/2020 4:14	61.3%
10.Removed	7/04/2020 20:30	19.6%