final report

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The effect of purge on the shelf life of vacuum packaged chilled beef

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Executive summary

The Egyptian market is an important alternative to Australia's main export markets for chilled meat. Whilst the production of purge during chilled storage of vacuum packaged beef product is generally considered an accepted event, the Egyptian market has in the past rejected Australian product on the basis that the presence of purge is suggestive of product that is no longer 'wholesome'. This study conducted microbiological, biochemical and sensory evaluations of stored vacuum packaged beef brisket, eye round and topside over a period of up to 32 weeks. Purge, lean and adipose tissue samples were analyses separately for TVC, Enterobacteriaceae, LAB and *Brochothrix thermosphacta*. As expected, microflora counts increased over time with TVC and LAB counts for lean and adipose samples from all muscle types rising from approximately 2.00 $log_{10}CFU/cm^2$ to <6.00 $log_{10}CFU/cm^2$ during 20 weeks of storage at -0.5°C. Microflora counts of purge samples were generally 1-2 $log_{10}CFU$ greater in magnitude than lean and adipose samples, however this is mostly attributable to the unit of measurement being analysed with lean and adipose tissue being measured per cm^2 and purge being measured per mL. The percentage of purge produced by eye round was greater than topside or brisket and maybe an important consideration when selecting export products for the Egyptian market. Sensory evaluation of vacuum, meat colour and fat colour pre- and post-bloom determined that although reductions in score values for each of the attributes occurred during storage, all samples, with the exception of topside fat colour at week 32, were considered acceptable. Odour scores for brisket and topside samples were acceptable up to and including 28 weeks of storage with odour scores for eye round samples remaining acceptable up to and including 20 of storage. Taste panel assessment determined that mean liking overall scores at week 20 were consistent with and often greater than the corresponding scores at zero, four and eight weeks of storage. Significant differences in mean liking overall scores were observed for brisket samples of weeks 24, 28 and 32 and topside samples from week 32 with these samples being adversely affected by elevated other flavour scores. This study has determined that the extended refrigerated (-0.5°C) storage of vacuum packaged beef brisket, eye round and topside along with the associated production of purge within these packs does not negatively impact expected spoilage rates or sensory aspects of these products for at least 20 weeks.

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1. Project objectives

- Determine the shelf life of three vacuum packaged chilled beef primals stored under usual commercial conditions.

2. Success in achieving milestone

This study has determined that vacuum packaged beef brisket, eye round and topside can be stored for at least 20 weeks at -0.5°C whilst retaining acceptable sensory characteristics and without exceeding microbiological concentrations typically associated with bacterial spoilage. These data should provide confidence that Australian beef exporters can access the Egyptian market using existing commercial conditions, distribution pathways, and with increased confidence around the acceptability of product.

3. Introduction

Purge, also called drip loss or weep, develops in vacuum packs of chilled meat. This is a natural phenomenon which is well recognised in most markets for chilled meat. The amount present in the pack increases with time of storage, can vary between cuts and is dependent on factors such as the pH of the meat, the initial cooling rate and the cross-sectional area of muscle fibres which have been cut.

The Egyptian market is an important alternative to Australia's main export markets for chilled meat. However issues have arisen in that market, over the presence of purge in vacuum packs of meat, mainly due to local perceptions and regulations. Markets that have been receiving beef exported from Australia for many years accept that purge is a normal phenomenon. However in Egypt, the presence of purge is being perceived in the marketplace as an indication that the meat is no longer 'wholesome'. This reasoning has been used to reject product.

MLA representatives have made several visits to Egypt to explain that purge is a normal occurrence and that it does not indicate that the product has exceeded its shelf life or is less 'wholesome'. The results of previous studies in Australia by CSIRO and others have been used to illustrate this point but the attitude in Egypt has persisted. In an effort to change this perception, this study evaluated the shelf life of three vacuum packaged beef primals chosen as being significant in the Egyptian, UAE and Japanese markets. These results will extend those previously obtained on beef striploins and cube rolls.

4. Materials and Methods

4.1. Samples

Vacuum packaged beef brisket (point end, deckle off, H.A.M code 2350), beef eye round (silver skin, H.A.M code 2040) and beef topside (H.A.M code 2000) sourced from an export registered Australian establishment were stored under refrigeration (-0.5°C ± 1°C) at the CSIRO Food and Nutrition laboratory. Upon arrival at CSIRO (week 0) and then every four weeks thereafter, three packs of brisket, eye round and topside were removed from storage and analysed using the methods outlined below. Samples for sensory analysis were collected at each time point and then frozen so that all taste panel sessions could be conducted at once following the completion of storage. A muscle type was removed from the trial if the average combined total viable count (TVC) of fat and adipose samples exceeded 7.5 $\log_{10}$CFU/cm^2.

4.2. Visual and olfactory analysis

Packs were assessed by an experienced panel for the following attributes: (i) standard of vacuum, (ii) appearance of the intact pack meat colour, (iii) appearance of the intact pack fat colour, (iv) the odour intensity on opening the pack, (v) appearance of meat colour after air exposure for 30 mins, (vi) appearance of fat colour after air exposure for 30 mins, and (vii) the odour intensity after 30 min exposure to air. The panel assessed these attributes on a 9-point scale with 8 being good vacuum, very fresh, no discolouration and no odour and 0 being no vacuum, severe discolouration and extreme off odour. The colour of the meat was measured using a Minolta Chromameter Model CR-400 (light source D65). The tristimulus values in Hunter coordinates (L*, a* and b*) were obtained after calibration with a standard white reflector. The colour was measured in the vacuum bag and then again after the meat had bloomed at 4˚C for >30 mins.

Following this initial assessment, the purge from each sample was collected and the volume measured. Using aseptic technique two excision samples were taken from each of the lean meat and adipose surfaces. Each excision sample was 10cm² in area, and lean meat and adipose tissue samples were processed separately for each sample. Muscle pH was measured on all primals at each storage time using a digital pH meter (TPS) fitted with a combination electrode (glass body with spear tip) with temperature compensation.

4.3. Microbiological analysis

Lean meat, adipose tissue and purge collected from each sample were analysed individually for total viable count (TVC), lactic acid bacteria (LAB), Enterobacteriaceae and *Brochothrix thermosphacta*. A 100 mL aliquot of 0.85% saline was added to stomacher bags containing lean meat or adipose tissue samples and samples were subsequently stomached for 30s. For purge samples a 1:10 dilution was made using 0.85% saline. Decimal dilution series were prepared in 0.85% saline and subsequently plated onto Petrifilm Aerobic, Petrifilm Enterobacteriaceae and STAA (Oxoid, Australia) plates for TVC, Enterobacteriaceae and *Brochothrix thermosphacta* counts, respectively. The dilutions were also prepared in MRS broth (Oxoid) and plated onto Petrifilm Aerobic according to the Petrifilm method for enumeration of LAB. Petrifilm Aerobic count plates were incubated at 25°C ± 1°C for 72 ± 3 h; Petrifilm Enterobacteriaceae plates were incubated at 35°C ± 1°C for 24 ± 2h; STAA plates were incubated aerobically at 22°C ± 1°C for 48 ± 2 h; LAB plates were incubated anaerobically at 25°C ± 1°C for 120 ± 3 h. Microbial counts were converted to $\log_{10}$CFU/cm^2 for lean and adipose samples and $\log_{10}$CFU/mL for purge samples.

4.4. Total volatile basic nitrogen (TVBN)

Analysis of TVBN values was conducted by Symbio Laboratories using Method Code CF048.1. A portion of each vacuum packaged muscle was provided to the laboratory within 2 hours of pack opening and sample preparation commenced upon arrival.

4.5. Lipid oxidation

The concentration of thiobarbituric reactive species (TBARS) was determined from minced muscle samples (Witte, Krause et al. 1970). Duplicate samples were capped and cooked in a 75°C water bath for 20 minutes and subsequently cooled for 30 minutes at 5°C prior to extraction. The concentration of malondialdehyde equivalents (mg/kg muscle) was calculated from absorbance readings at 530nm, using 1,1,3,3-tetraethoxypropane as a standard.

4.6. Sensory analysis

Frozen steaks were thawed at 4˚C for 24h prior to tasting. The steaks were weighed and placed on numbered trays and kept at 4˚C prior to cooking. Steaks were cooked on a Silex clam shell grill unit, set at 230˚C with the lid closed. The griller was switched on 30 minutes prior to cooking and the temperature of the top and bottom plate were measured with an infrared thermometer before placing the steaks on the grill. After cooking, the surface temperature of the steaks was measured with the infrared thermometer and the cooked weight determined. Steaks were then transferred to a cutting board, covered and rested for 2 minutes before being sliced into 1cm cubes. Two cubes were placed into a numbered beaker, covered and placed into a warming oven at 50˚c for approximately 10 minutes prior to serving.

A 10-member panel of assessors participated in the sensory analysis with the panel ranging in age from 30 to 55 years. There were 4 male and 6 female panellists comprising a range of nationalities and ethnic backgrounds. Formal evaluation sessions were held over 72 hours, 3 sessions per day of each muscle and within each 30 minute trial, between six and nine samples were assessed. Samples were provided in randomly ordered coded glass beakers with clear plastic lids. A randomised presentation design was used within each replicate for all trials. Formal evaluations were conducted in the sensory laboratory at the Health and Food Sciences Precinct at Coopers Plains, Brisbane, which contains twelve isolated booths equipped with computers, temperature control (22°C) and under day-light equivalent lighting. During the sessions, the panel were provided with water for cleansing of the palette in between samples. Panellists were asked to utilise a flavour and odour reference guide for grilled beef and then evaluate each sample, rating the intensity of the attributes using an unstructured 15cm line scale (0-10).

5. Results and Discussion

5.1. Microbiological analysis

TVC increased in magnitude during storage for all muscle types and all sample types. No substantial differences were observed between lean and adipose tissue samples. Mean TVC at week 0 were ≤2.00 $log_{10}CFU/cm^2$ and remained less than 6.00 $log_{10}CFU/cm^2$ after 20 weeks of storage. TVC of purge samples mirrored those of the lean and adipose samples but were greater in magnitude. However, the differences observed in the magnitude of TVC between purge samples and lean and adipose samples would appear to be a function of the units being analysed with purge samples being analysed per mL and lean and adipose tissues analysed per cm^2. TVC was used as the primary criteria for ongoing inclusion of a muscle type in the study. On this basis, both the beef brisket and beef topside samples were included in the trial for the entire 32 weeks. Beef Eye round samples were removed after week 24 as they were deemed to have spoiled at this point. A summary of TVC for brisket (PP), eye round (ST) and topside (SM) are shown in Figures 1-3 below. The mean TVC data is shown in tabular format in Appendix 1.

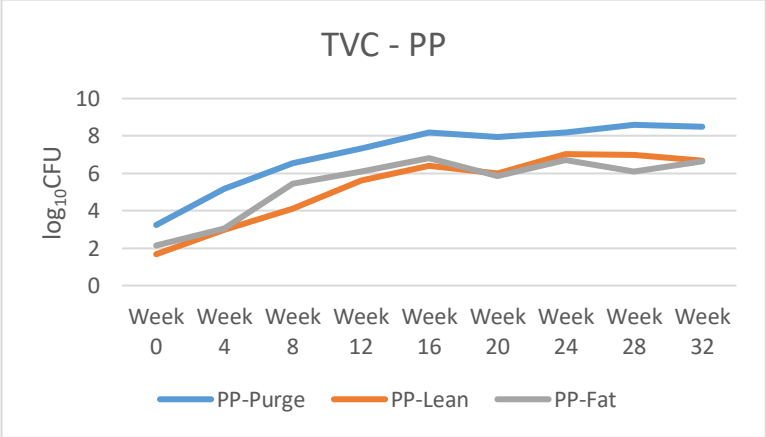

Figure 1. Mean TVC of purge ($log_{10}CFU/mL$), lean and adipose ($log_{10}CFU/cm^2$) samples from vacuum packaged beef brisket

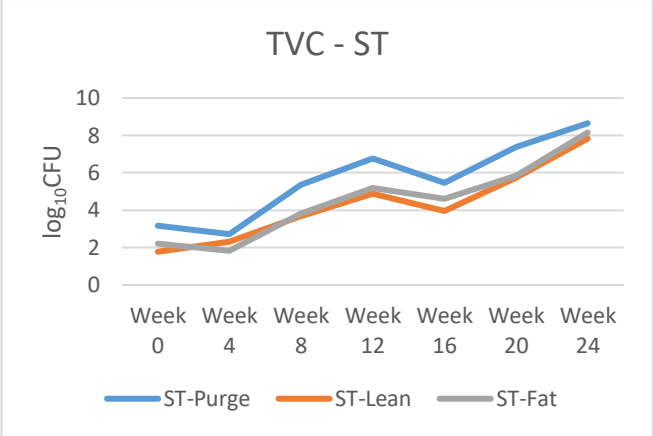

Figure 2. Mean TVC of purge (log_{10}CFU/mL), lean and adipose (log_{10}CFU/cm^2) samples from vacuum packaged beef eye round

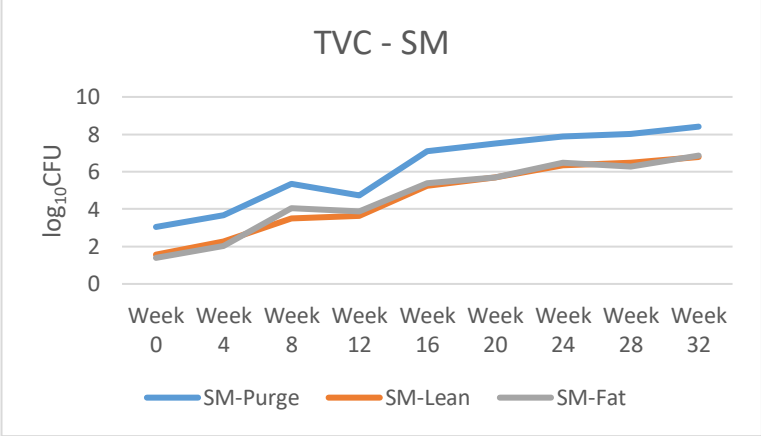

Figure 3. Mean TVC of purge (log_{10}CFU/mL), lean and adipose (log_{10}CFU/cm^2) samples from vacuum packaged beef topside

As is expected with vacuum packaged beef products, the concentration of LAB increased progressively during storage. The concentration of LAB in all sample types from all muscles was highly correlated with the corresponding TVC values, rising from ≤2.00 log_{10}CFU/cm^2 at week 0 to <6.00 log_{10}CFU/cm^2 after 20 weeks of storage, suggesting that LAB were the dominant microflora present during storage. Significant differences in LAB concentrations between lean and adipose samples were not observed and although the concentration of LAB in purge samples was typically higher than lean and adipose samples, the differences are once again most likely attributable to the unit of analysis as opposed to the presence of distinct microbial populations. A summary of LAB counts for brisket (PP), eye round (ST) and topside (SM) are shown in Figures 4-6 below. The mean LAB count data is shown in tabular format in Appendix 1.

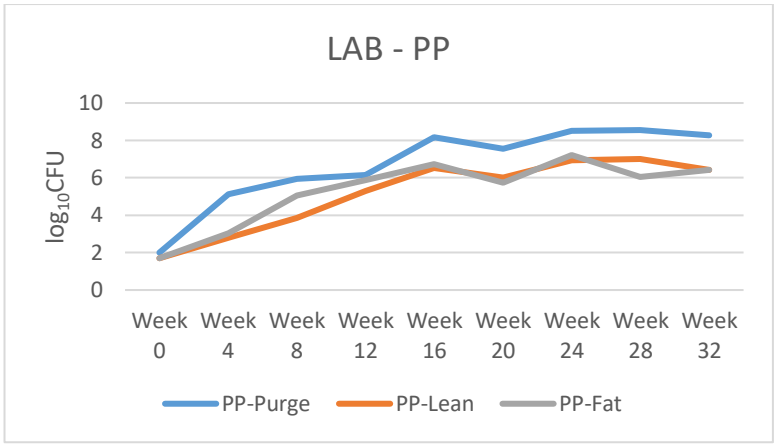

Figure 4. Mean LAB count of purge (log_{10}CFU/mL), lean and adipose (log_{10}CFU/cm^2) samples from vacuum packaged brisket

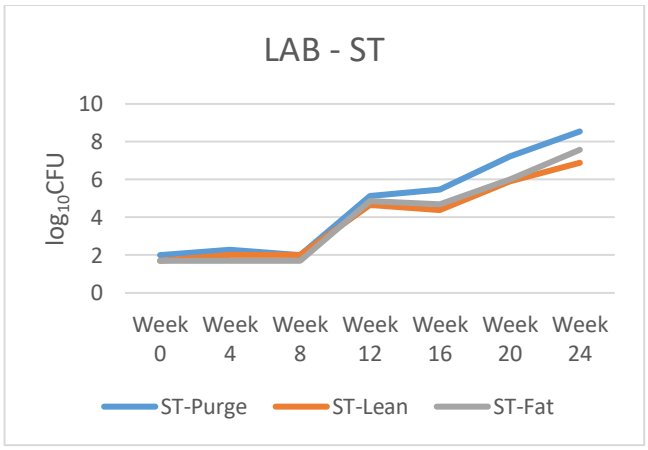

Figure 5. Mean LAB count of purge (log_{10}CFU/mL), lean and adipose (log_{10}CFU/cm^2) samples from vacuum packaged eye round

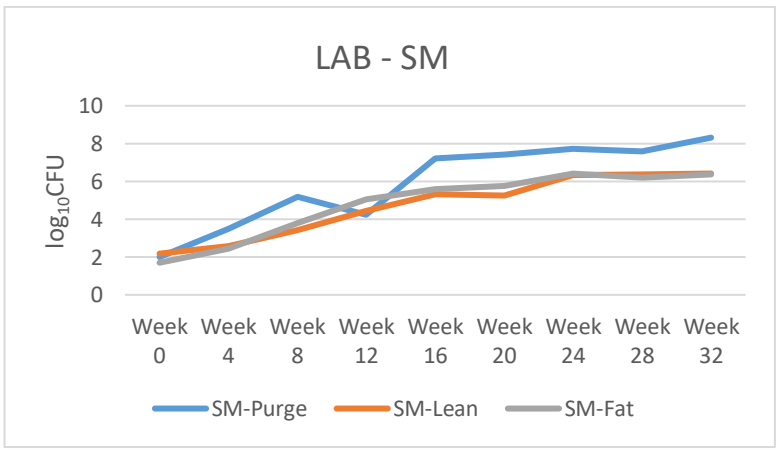

Figure 6. Mean LAB count of purge (log_{10}CFU/mL), lean and adipose (log_{10}CFU/cm^2) samples from vacuum packaged topside

Enterobacteriaceae counts of lean and adipose samples did not exceed 3.00 $log_{10}CFU/cm^2$ until week 12 for brisket and eye round and week 16 for topside. In general, Enterobacteriaceae counts from purge samples demonstrated the same relationship to lean and adipose samples as had been observed with TVC and LAB counts. However, on occasion there were differences between the concentrations in purge from those in lean or adipose samples that exceeded 2.00 $log_{10}CFU$. Differences of this magnitude were more common in the latter stages of storage but would appear to be greater than those attributable to the unit of analysis alone. Additional investigation may determine if the concentrations of Enterobacteriaceae in purge are due to natural variability or are a result of more favourable growth conditions. A summary of Enterobacteriaceae counts for brisket (PP), eye round (ST) and topside (SM) are shown in Figures 7-9 below. The mean Enterobacteriaceae count data is shown in tabular format in Appendix 1.

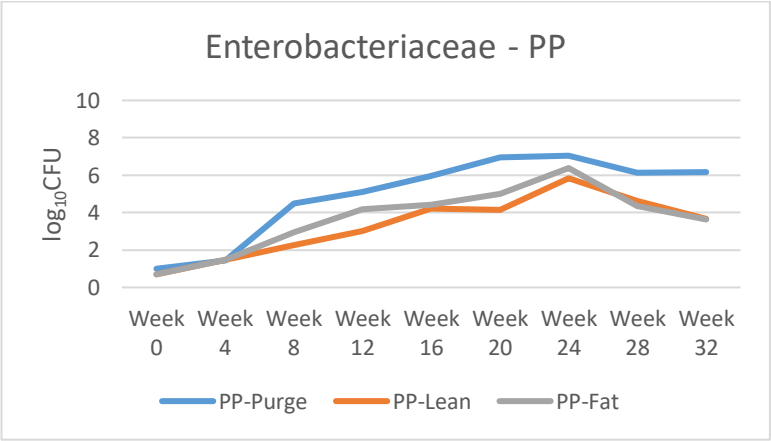

Figure 7. Mean Enterobacteriaceae count of purge ($log_{10}CFU/mL$), lean and adipose ($log_{10}CFU/cm^2$) samples from vacuum packaged beef brisket

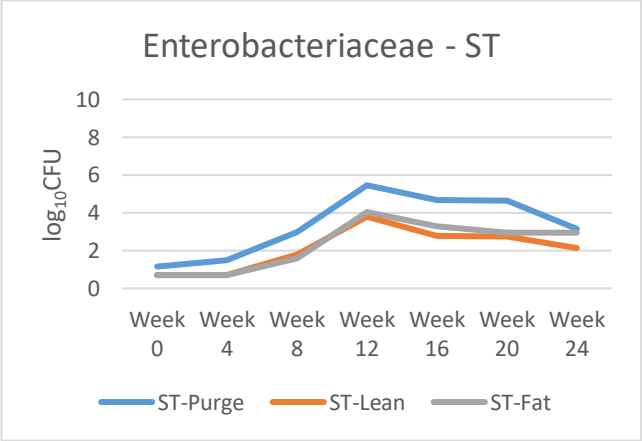

Figure 8. Mean Enterobacteriaceae count of purge ($log_{10}CFU/mL$), lean and adipose ($log_{10}CFU/cm^2$) samples from vacuum packaged beef eye round

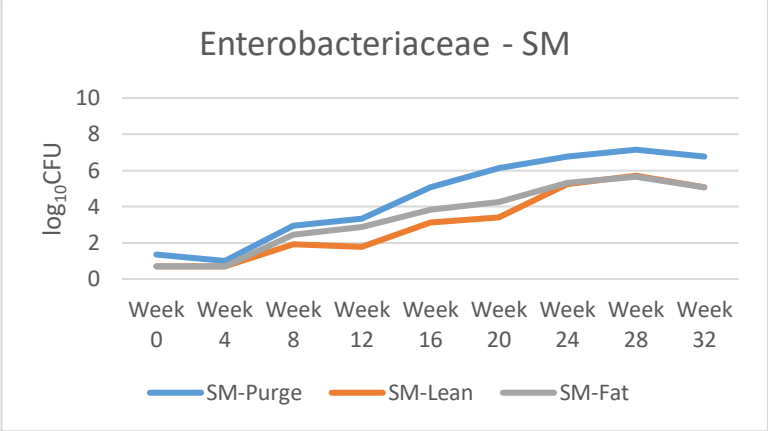

Figure 9. Mean Enterobacteriaceae count of purge (log_{10}CFU/mL), lean and adipose (log_{10}CFU/cm^2) samples from vacuum packaged beef topside

Brochothrix thermosphacta was not detected in any eye round samples but were detected in lean and adipose samples from brisket in week 4 onwards and in topside from week 8 onwards. Mean counts >4.00 log_{10}CFU/cm^2 were observed in brisket adipose samples collected at week 8 and in lean and adipose samples collected at week 12. Counts appeared to then stabilise at around 3.00 log_{10}CFU/cm^2 for samples through to 20 weeks of storage. Counts of *Brochothrix thermosphacta* in purge samples did mirror the lean and adipose samples although there were occasions (e.g. brisket week 20) where the difference was greater than what could be explained by variations in the unit of analysis. A summary of *Brochothrix thermosphacta* counts for brisket (PP) and topside (SM) are shown in Figures 10 and 11 below. The mean *Brochothrix thermosphacta* count data is shown in tabular format in Appendix 1.

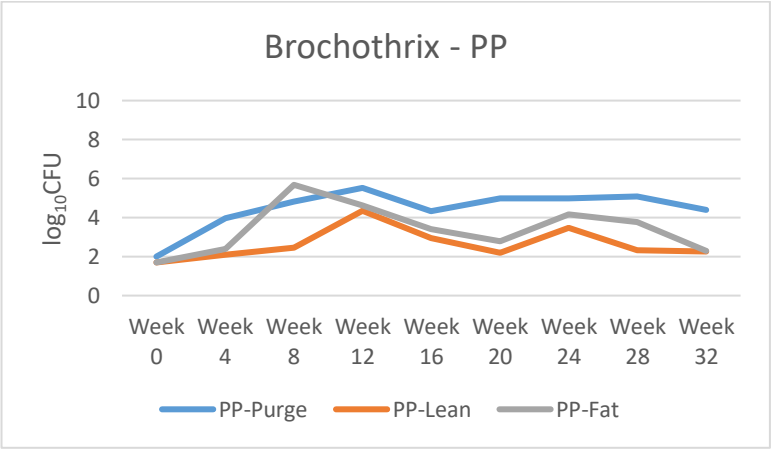

Figure 10. Mean *Brochothrix thermosphacta* count of purge (log_{10}CFU/mL), lean and adipose (log_{10}CFU/cm^2) samples from vacuum packaged beef brisket

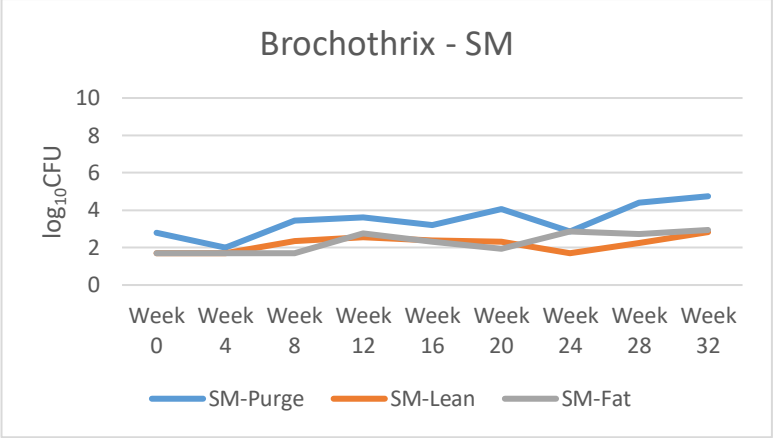

Figure 11. Mean *Brochothrix thermosphacta* count of purge (log_{10}CFU/mL), lean and adipose (log_{10}CFU/cm^2) samples from vacuum packaged beef topside

5.2. Purge percentage

The percentage of purge for each muscle type is shown in Figure 12. Small to moderate increases in purge percentage were observed for brisket and topside, respectively. Mean purge percentages for brisket ranged from 0.03% (week 0) to 1.06% (week 28) and 1.4% (week 0) to 3.13% (week 24) for topside. Conversely, the purge percentage associated with the eye round samples rose in a linear sense from 0.76% (week 0) through to 6.26% (week 24). Eye round represented the smallest muscle used in this study and therefore percentage of purge would be more greatly affected by small changes in purge volume than brisket or topside. Nonetheless, in many samples the volume of purge recovered from eye round samples exceeded that which was recovered from brisket or topsides.

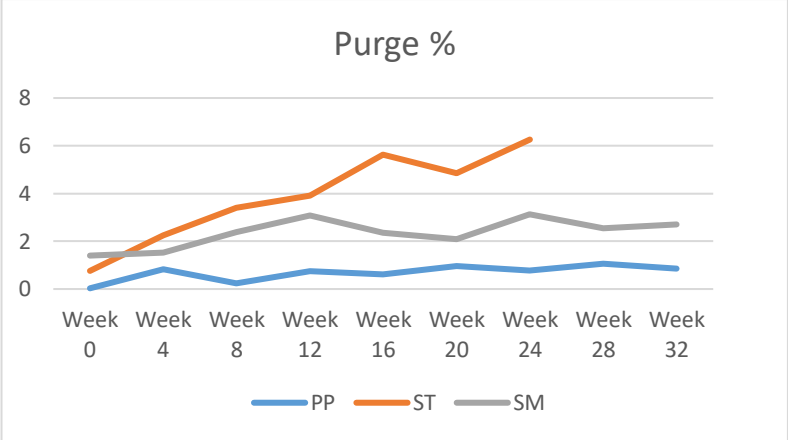

Figure 12. Purge percentages (purge (mL)/meat wt (g)) of vacuum packaged brisket, eye round and topside stored for up to 32 weeks

5.3. pH

Mean pH values for all muscle types at all sampling points was ≤5.80 (Figure 13). Two brisket samples at week 8 and a brisket sample at week 12 had pH values greater than 5.80 with the maximum pH for the study recorded as 5.87. The pH data would suggest that the majority of the samples included in this study were within a pH range considered normal for vacuum packaged beef regardless of storage time or muscle type.

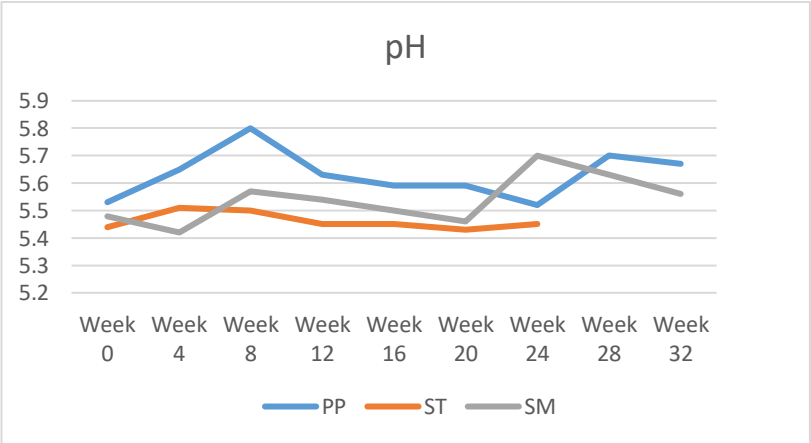

Figure 13. Mean pH values for vacuum packaged brisket, eye round and topside stored for up to 32 weeks

5.4. Total volatile basic nitrogen (TVBN)

TVBN values are used as indicators of freshness and are expected to increase in value during the vacuum packaged storage of beef products as a result of increasing levels of microbial contamination. In this study

TVBN correlated poorly with microbial counts. With the exception of week 24 samples, minimal differences in TVBN values was observed across samples with just 0.66 mg/100g separating the week 0 and week 32 samples. Substantial variability was observed with eye round and topside samples over the first 12 weeks of storage with weeks 4 and 12 values for eye round and week 12 values for topside being below the limit of detection. An increase was noted for eye round samples at week 16, however no further increase was observed in weeks 20 or 24.

Table 1. Average TVBN (mg/100g) values for vacuum packaged brisket, eye round and topside stored for up to 32 weeks

Muscle	Week								
	0	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**
PP	35.67	<1.0	30.00	35.00	49.00	31.33	67.00	39.33	36.33
ST	27.67	<1.0	28.67	<1.0	47.67	40.00	47.00	NT*	NT
SM	22.33	<1.0	28.00	15.33	46.67	41.67	49.33	45.00	47.67

* NT – not tested

5.5. Lipid oxidation

In general, TBAR values are expected to increase during storage time. This trend was observed for brisket and eye round muscles, however topside muscles trended slightly downwards during the trial (Figure 14). The downward trend observed with topside is heavily influenced by an elevated average reading at week 0 and a low average reading at week 24. Removal of week 0 and 24 data would result in a trend line with similar slope to the brisket and eye round trend lines suggesting that in general, lipid oxidation occurred at a relatively similar rate for all muscle types.

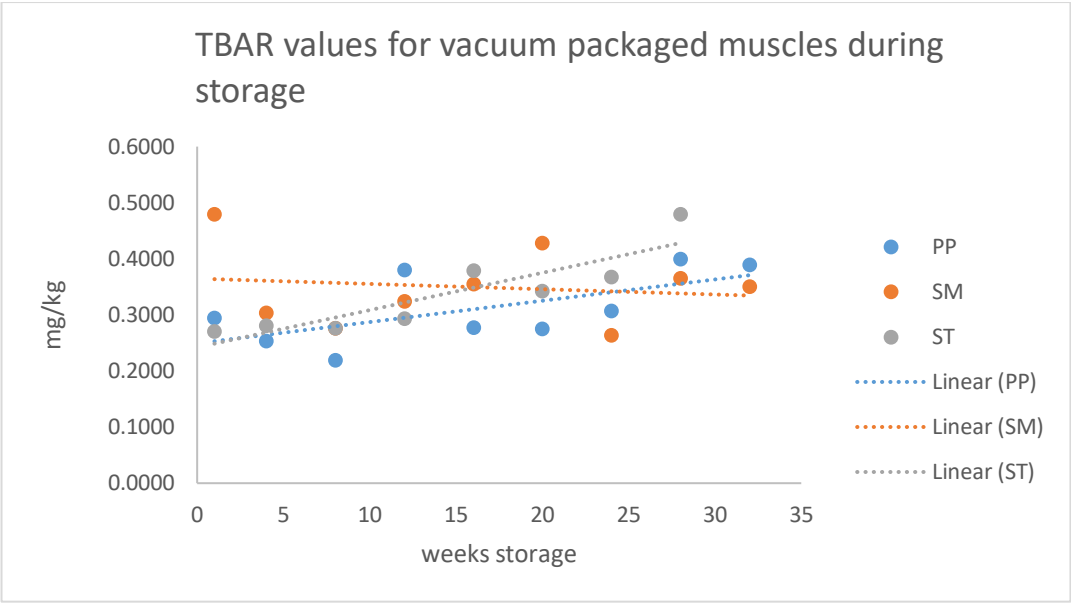

Figure 14. Average TBAR values of vacuum packaged brisket, eye round and topside stored for up to 32 weeks

5.6. Minolta colourimetry

Average meat colour readings for pre- and post-bloom vacuum packaged brisket, eye round and topside are shown in Figures 15 and 16. Tabulated data and standard errors for each sample set are presented in Appendix 1. Pre- and post-bloom scores remained relatively unchanged with only a slight downward trend evident through 24 weeks of storage regardless of muscle type. Decreases in lightness (L) values were observed for pre-bloom brisket and topside from 28 weeks onwards.

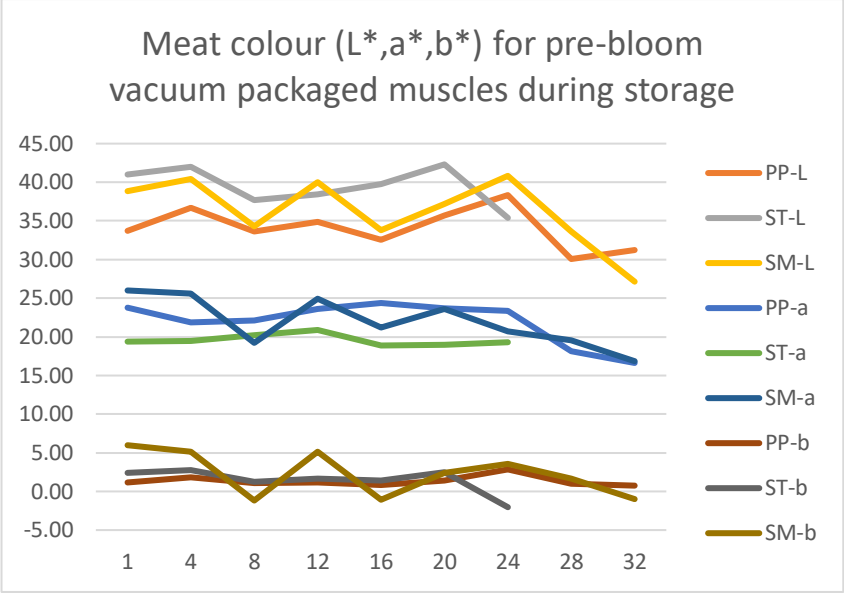

Figure 15. Average Minolta colour scores for pre-bloom vacuum packaged brisket, eye round and topside stored for up to 32 weeks

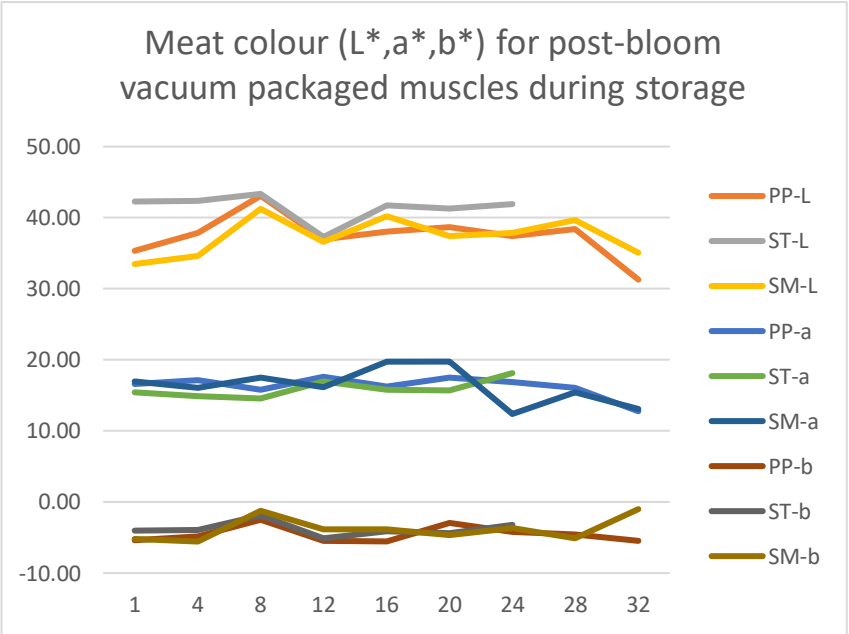

Figure 16. Average Minolta colour scores for post-bloom vacuum packaged brisket, eye round and topside stored for up to 32 weeks

5.7. Sensory evaluation

5.7.1. Visual and olfactory

All samples were assessed by a panel for vacuum, meat colour and fat colour prior to opening of the vacuum packs and then again for meat colour, fat colour 30 minutes after opening. Odour scores were also recorded upon pack opening and then again after 30 minutes exposure to air. Average scores for each criteria are shown in Tables 2-8 below. For all assessed criteria a score of >4.00 was deemed acceptable. As expected the scores for vacuum, meat colour and fat colour of unopened product did reduce over time. Nevertheless all samples, with the exception of topside fat colour at week 32, remained acceptable to the assessment panel. The meat and fat colour scores and trends were replicated post-bloom with only the topside fat colour at week 32 considered unacceptable. Odour scores upon pack opening and 30 minutes post-opening declined over time but were acceptable for all muscles up to and including week 20. Brisket samples had acceptable odour upon opening throughout the 32 week trial but was considered unacceptable 30 minutes post-opening at week 32. Similarly the odour scores for topside samples upon opening and 30 minutes post-opening were found to be unacceptable. Eye round samples at week 24 were unacceptable for odour upon opening and 30 minutes post-opening.

Table 2. Vacuum score for three beef cuts

Storage time (w)	PP	ST	SM
0	7.77	7.47	7.67
4	7.17	5.50	7.62
8	7.23	4.48	7.28
12	5.86	4.30	7.13
16	5.67	5.57	6.14
20	6.08	5.08	6.29
24	5.38	4.52	6.71
28	6.29	NT*	6.25
32	4.74	NT	4.33

* NT – not tested; PP = brisket; ST = eye round and SM = topside

Table 3. Intact pack meat colour for three beef cuts

Storage time (w)	PP	ST	SM
0	7.77	7.53	7.73
4	7.37	6.58	7.15
8	6.72	6.07	6.53
12	6.33	5.60	6.23
16	6.43	5.71	6.00
20	5.88	5.13	5.92
24	5.86	4.86	6.14
28	5.46	NT*	5.42
32	5.30	NT	4.30

* NT – not tested; PP = brisket; ST = eye round and SM = topside

Table 4. Intact pack fat colour for three beef cuts

Storage time (w)	PP	ST	SM
0	7.57	7.00	7.47
4	7.27	6.40	6.93
8	6.53	5.80	6.32
12	6.50	5.83	6.40
16	6.05	5.67	5.81
20	5.63	5.13	5.38
24	5.76	4.62	5.52
28	5.42	NT*	4.88
32	4.52	NT	2.30

* NT – not tested; PP = brisket; ST = eye round and SM = topside

Table 5. Meat colour post-bloom for three beef cuts

Storage time (w)	PP	ST	SM
0	7.93	7.67	7.87
4	7.77	7.42	7.47
8	7.22	7.03	7.23
12	6.87	5.93	6.67
16	6.95	6.33	6.19
20	6.54	5.79	6.38
24	6.10	4.90	6.14
28	6.08	NT*	5.83
32	5.93	NT	5.15

* NT – not tested; PP = brisket; ST = eye round and SM = topside

Table 6. Fat colour post bloom for three beef cuts

Storage time (w)	PP	ST	SM
0	7.77	7.60	7.67
4	7.77	7.00	7.28
8	7.07	7.03	6.90
12	6.74	5.93	6.20
16	6.95	6.10	5.81
20	5.79	5.71	5.42
24	5.86	5.19	5.57
28	5.96	NT*	4.88
32	5.30	NT	3.48

* NT – not tested; PP = brisket; ST = eye round and SM = topside

Table 7: Odour upon opening for three beef cuts

Storage time (w)	PP	ST	SM
0	7.80	7.53	7.97
4	7.30	6.23	7.63
8	6.95	5.97	6.93
12	6.37	6.53	6.37
16	6.43	4.95	6.81
20	5.75	5.00	6.25
24	4.48	2.95	5.57
28	5.17	NT*	5.21
32	4.00	NT	1.96

* NT – not tested; PP = brisket; ST = eye round and SM = topside

Table 8: Odour 30 minutes post-opening for three beef cuts

Storage time (w)	PP	ST	SM
0	7.97	7.60	8.00
4	7.70	7.10	7.90
8	7.08	5.70	6.97
12	6.28	5.67	6.40
16	6.67	4.67	6.43
20	5.63	5.21	6.04
24	5.05	2.38	5.48
28	5.29	NT*	5.21
32	3.74	NT	1.96

* NT – not tested; PP = brisket; ST = eye round and SM = topside

5.7.2. Taste

Grilled beef samples were prepared for each muscle type and assessed using a 10-point scale with scores above five for any attribute considered acceptable. The taste panel sessions comprised all brisket and topside samples and eye round samples up to and including week 20. The remaining eye round samples (weeks 24 to 32) were excluded based on available microbiological data. Percentage cook-loss was calculated for all samples and average percentages at each time point are shown in Figure 17. Percentage cook-loss tended to increase with storage time with maximum cook-loss percentages observed at weeks 28, 16 and 32 for brisket, eye round and topside, respectively.

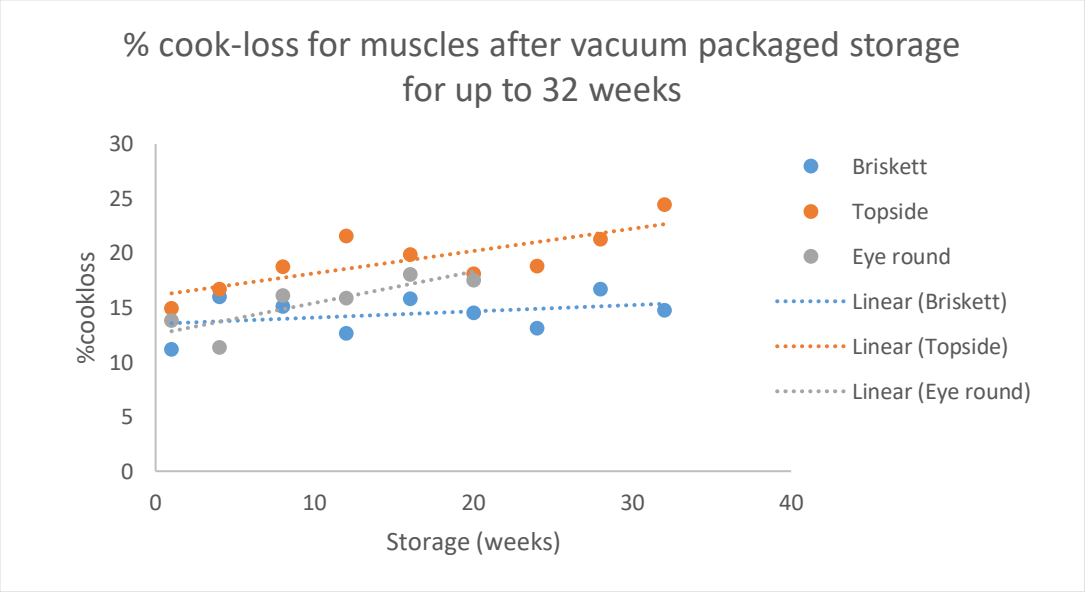

Figure 17. Mean percentage cook-loss for vacuum packaged brisket, eye round and topside samples stored for up to 32 weeks

The taste panel sessions assessed each sample for nine attributes which when combined permitted scoring for liking aroma, liking flavor and liking overall (Figures 18 to 20). Average taste panel scores for all assessed attributes are shown in Appendix 1. It must be noted that grilling beef from the brisket, eye round or topside is a less favoured way to prepare these types of cuts and it is most likely that they would be prepared roasted, braised or as a casserole. Consequently importance should be placed on comparing scores across storage times for each muscle as opposed to focusing on the magnitude of the actual scores.

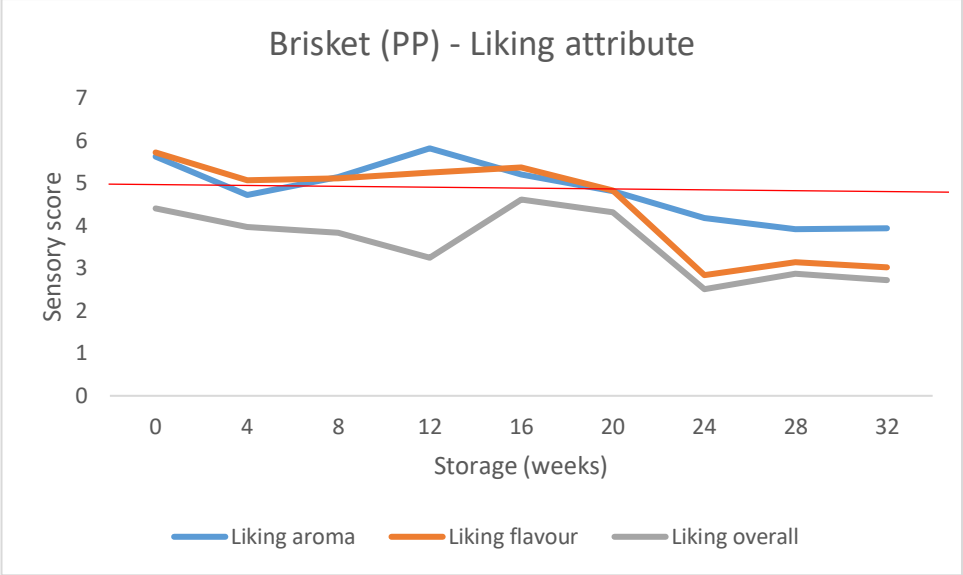

Figure 18. Average liking scores for aroma, flavor and overall for vacuum packaged brisket stored for 32 weeks (red horizontal line indicates the acceptable/not acceptable breakpoint)

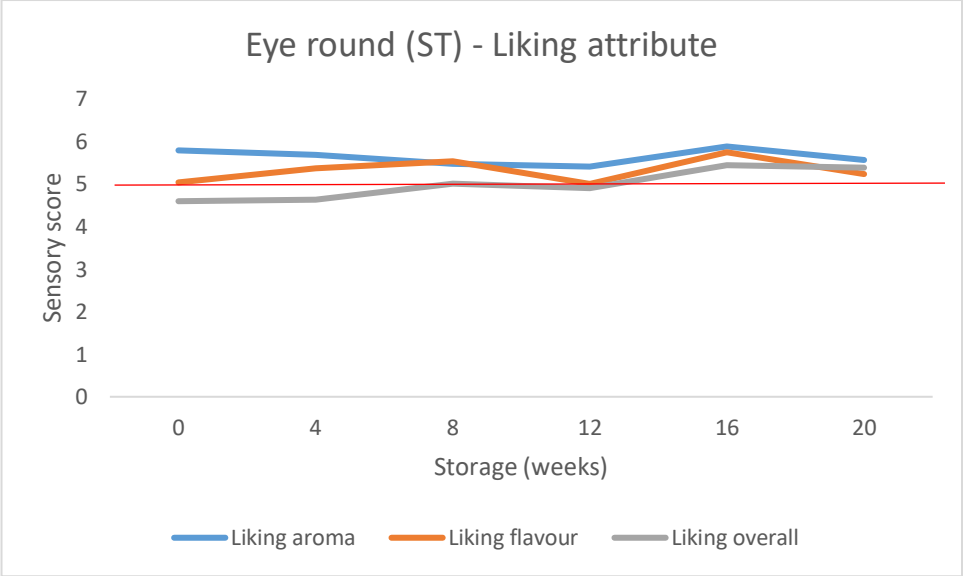

Figure 19. Average liking scores for aroma, flavor and overall for vacuum packaged eye round stored for 20 weeks (red horizontal line indicates the acceptable/not acceptable breakpoint)

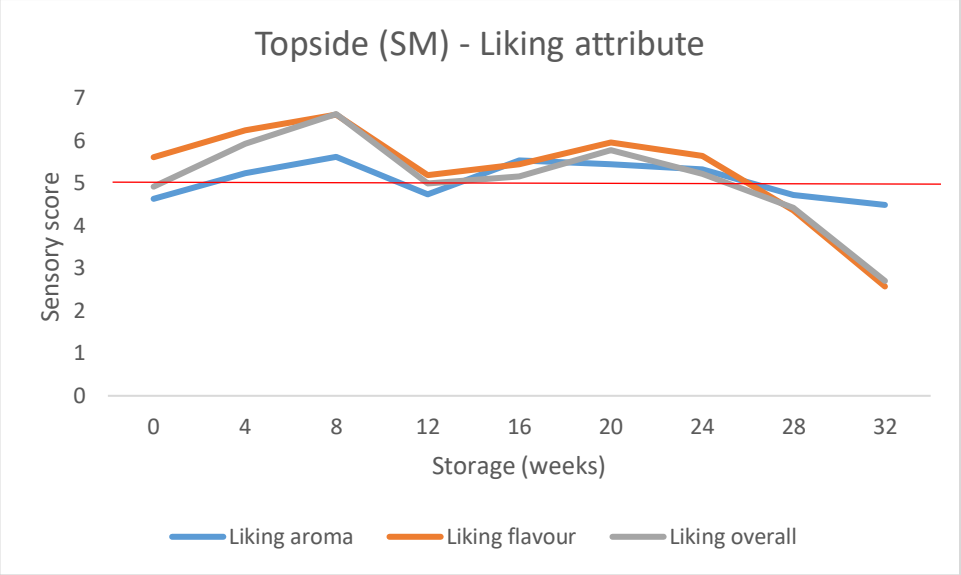

Figure 20. Average liking scores for aroma, flavor and overall for vacuum packaged topside stored for 32 weeks (red horizontal line indicates the acceptable/not acceptable breakpoint)

The mean score for overall liking of brisket samples was 4.41 at week 0 and in general fell over time to 2.72 at week 32. A spike in overall liking was observed at weeks 16 and 20 and is most correlated with increases in meat tenderness scores. Overall mean liking scores for samples in weeks 24, 28 and 32 were significantly ($p=0.028$) lower and were associated with substantial increases in scores for other flavour. The average scores for overall liking of eye round samples rose slightly during the 20 weeks of storage from 4.60 to 5.38. The slight increase in overall liking was associated with commensurate increases in meat tenderness (4.01 at week 0 to 6.16 at week 20) during storage. All other attributes for eye round samples were relatively stable during storage. Mean overall liking scores for topside samples increased steadily during the first 8 weeks of storage from 4.92 to 6.62. Mean overall liking scores remained above the week 0 overall liking score until week 28 where a small though not significant drop in acceptability was observed. The mean overall liking score of 2.70 at week 32 represents a significant ($p=0.05$) outlier from the mean overall liking scores observed for weeks one to 24 and as was the case with the brisket samples, was associated by an increase in mean score for other flavour.

6. Summary

The Egyptian market is an important alternative to Australia's main export markets for chilled meat. Whilst the use of vacuum packaging and the associated production of purge during storage of vacuum packaged beef product is generally considered an accepted event, the Egyptian market has in the past rejected Australian product on the basis that the presence of purge is suggestive of product that is no longer 'wholesome'. This study conducted microbiological, biochemical and sensory evaluations of stored vacuum packaged brisket, eye round and topside over a period of up to 32 weeks. Purge, lean and adipose tissue samples were analysed separately for TVC, Enterobacteriaceae, LAB and *Brochothrix thermosphacta*. As expected, microflora counts increased over time with TVC and LAB counts for lean and adipose samples from all muscle types rising from approximately 2.00 $log_{10}CFU/cm^2$ to <6.00 $log_{10}CFU/cm^2$ during 20 weeks of storage. Microflora counts of purge samples were generally 1-2 $log_{10}CFU$ greater in magnitude than lean and adipose samples, however this is mostly attributable to the unit of measurement being analysed with lean and adipose tissue being measured per cm^2 and purge being measured per mL. Differences between microflora counts of purge samples and lean and adipose tissue samples occasionally exceeded 2.0 $log_{10}CFU$. These differences were more likely to occur in the latter stages of storage (i.e post 16 weeks) and were mainly related to Enterobacteriaceae concentrations.

The percentage of purge produced by different muscle types was variable and maybe an important consideration when selecting export products for the Egyptian market. Whilst purge percentage was relativity consistent and low in brisket (0.03 – 1.06%) and topside (1.4 – 3.13%), the purge volume and percentage for eye round rose steadily during storage from 0.76 (week 0) to 6.76% (week 24). Substantial differences in lipid oxidation and pH trends or values were not observed between muscle types and along with TVBN would appear to be of little assistance in determining the suitability of product for the Egyptian market. Sensory evaluation of vacuum, meat colour and fat colour pre- and post-bloom determined that although reductions in score values for each of the attributes occurred during storage, all samples, with the exception of topside fat colour at week 32, were considered acceptable. Odour scores for brisket and topside samples upon pack opening and after 30 minutes exposure to air were acceptable up to and including 28 weeks of storage. Odour scores for eye round samples remained acceptable up to an including 20 and weeks of storage for odour upon opening and odour 30 minutes after exposure to air, respectively. Taste panel assessment determined that mean liking overall scores at week 20 were consistent with and often greater than the corresponding scores at zero, four and eight weeks of storage. Significant differences in mean liking overall scores were observed for brisket samples of weeks 24, 28 and 32 and

topside samples from week 32 with these samples being adversely affected by elevated other flavour scores.

7. Conclusion

This study has determined that the extended refrigerated storage of vacuum packaged Australian beef brisket, eye round and topside along with the associated production of purge within these packs does not negatively impact expected spoilage rates or sensory aspects of these products for at least 20 weeks.

8. Acknowledgments

The Authors of this report wish to acknowledge the valuable contribution made by staff members of CSIRO Food and Nutrition and the Queensland Department of Agriculture and Fisheries through their participation in the sensory analysis panels conducted during this study.

9. References

Witte, V. C., Krause, G. F., & Bailey, M. E. (1970). A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. *Journal of Food Science, 35*, 582

10. Appendix 1

Table 1.1. Mean microbiological counts for TVC, LAB, Enterobacteriaceae (EB) and *Brochothrix thermosphacta* (*B. thermo*) in purge, lean tissue and adipose tissue from vacuum packaged brisket, eye round and topside

TVC	Week 0	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32
PP-Purge	3.24	5.19	6.56	7.32	8.18	7.94	8.17	8.60	8.49
PP-Lean	1.68	2.97	4.11	5.61	6.40	5.99	7.03	6.97	6.68
PP-Fat	2.15	3.06	5.45	6.09	6.81	5.85	6.73	6.09	6.66
ST-Purge	3.19	2.72	5.35	6.75	5.48	7.38	8.65	NT	NT
ST-Lean	1.78	2.30	3.67	4.88	3.97	5.75	7.83	NT	NT
ST-Fat	2.22	1.83	3.82	5.20	4.62	5.86	8.16	NT	NT
SM-Purge	3.05	3.67	5.36	4.72	7.10	7.52	7.88	8.02	8.41
SM-Lean	1.57	2.27	3.49	3.64	5.23	5.70	6.36	6.46	6.79
SM-Fat	1.39	2.03	4.04	3.87	5.39	5.70	6.47	6.26	6.86

EB	Week 0	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32
PP-Purge	1.00	1.45	4.48	5.11	5.98	6.95	7.04	6.13	6.17
PP-Lean	0.70	1.48	2.28	3.00	4.22	4.15	5.84	4.61	3.66
PP-Fat	0.70	1.48	2.96	4.17	4.42	5.01	6.38	4.36	3.63
ST-Purge	1.15	1.48	2.96	5.45	4.67	4.65	3.14	NT	NT
ST-Lean	0.70	0.70	1.79	3.79	2.78	2.73	2.13	NT	NT
ST-Fat	0.70	0.70	1.58	4.03	3.30	2.94	2.96	NT	NT
SM-Purge	1.37	1.00	2.93	3.33	5.06	6.14	6.78	7.14	6.77
SM-Lean	0.70	0.70	1.91	1.78	3.13	3.40	5.24	5.71	5.07
SM-Fat	0.70	0.70	2.44	2.86	3.83	4.24	5.32	5.65	5.08

LAB	Week 0	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32
PP-Purge	2.00	5.12	5.96	6.15	8.17	7.57	8.51	8.55	8.26
PP-Lean	1.70	2.80	3.86	5.30	6.51	6.03	6.94	7.01	6.41
PP-Fat	1.70	3.05	5.07	5.87	6.72	5.73	7.22	6.03	6.44
ST-Purge	2.00	2.30	2.00	5.13	5.47	7.24	8.54	NT	NT
ST-Lean	1.70	2.00	2.00	4.67	4.40	5.91	6.89	NT	NT
ST-Fat	1.70	1.70	1.70	4.87	4.69	6.00	7.57	NT	NT
SM-Purge	2.00	3.50	5.20	4.22	7.20	7.43	7.74	7.61	8.32
SM-Lean	2.18	2.59	3.44	4.45	5.32	5.25	6.35	6.38	6.42
SM-Fat	1.70	2.43	3.79	5.05	5.59	5.77	6.41	6.20	6.38

B. thermo	Week 0	Week 4	Week 8	Week 12	Week 16	Week 20	Week 24	Week 28	Week 32
PP-Purge	2.00	3.97	4.81	5.52	4.32	4.97	4.98	5.07	4.40
PP-Lean	1.70	2.09	2.45	4.35	2.95	2.18	3.48	2.32	2.26
PP-Fat	1.70	2.40	5.68	4.62	3.42	2.77	4.16	3.76	2.30
ST-Purge	2.00	2.00	2.00	2.00	2.00	2.00	2.00	NT	NT
ST-Lean	1.70	1.70	1.70	1.70	1.70	1.70	1.70	NT	NT
ST-Fat	1.70	1.70	1.70	1.70	1.70	1.70	1.70	NT	NT
SM-Purge	2.81	2.00	3.45	3.61	3.21	4.05	2.85	4.39	4.75
SM-Lean	1.70	1.70	2.36	2.54	2.40	2.30	1.70	2.25	2.83
SM-Fat	1.70	1.70	1.70	2.75	2.30	1.94	2.85	2.72	2.94

Table 1.2. Mean values (± std error) for lightness (L*), redness (a*) and yellowness (b*) for beef brisket, eye round and topside measured prior to opening

	Week	**Brisket**		**Eye Round**		**Topside**	
L*		x	se	x	se	x	se
	0	35.35	±20.41	42.28	±24.41	33.48	±19.33
	4	37.81	±21.83	42.32	±24.43	34.57	±19.96
	8	43.08	±24.87	43.34	±25.02	41.24	±23.81
	12	36.92	±21.31	37.28	±21.52	36.57	±21.11
	16	38.00	±21.94	41.73	±24.09	40.19	±23.20
	20	38.64	±22.31	41.30	±23.84	37.44	±21.62
	24	37.39	±21.59	41.89	±24.18	37.81	±21.83
	28	38.42	±22.18	NT	NA	39.65	±22.89
	32	31.28	±18.06	NT	NA	35.04	±20.23
a*							
	0	16.64	±9.61	15.39	±8.89	17.00	±9.81
	4	17.14	±9.90	14.87	±8.59	16.02	±9.25
	8	15.77	±9.10	14.56	±8.41	17.47	±10.09
	12	17.61	±10.17	17.00	±9.81	16.15	±9.33
	16	16.28	±9.40	15.83	±9.14	19.74	±11.40
	20	17.48	±10.09	15.74	±9.09	19.71	±11.38
	24	16.90	±9.76	18.13	±10.47	12.38	±7.15
	28	16.10	±9.30	NT	NA	15.41	±8.90
	32	12.76	±7.37	NT	NA	13.10	±7.57
b*							
	0	-5.35	±-3.09	-4.00	±-2.31	-5.22	±-3.02
	4	-4.84	±-2.79	-3.90	±-2.25	-5.57	±-3.22
	8	-2.50	±-1.44	-1.89	±-1.09	-1.25	±-0.72
	12	-5.45	±-3.15	-5.11	±-2.95	-3.87	±-2.23
	16	-5.55	±-3.20	-4.11	±-2.37	-3.85	±-2.22
	20	-2.93	±-1.69	-4.36	±-2.52	-4.65	±-2.68
	24	-4.18	±-2.42	-3.24	±-1.87	-3.65	±-2.11
	28	-4.60	±-2.65	NT	NA	-5.12	±-2.96
	32	-5.48	±-3.16	NT	NA	-1.01	±-0.58

Table 1.3. Mean values (± std error) for lightness (L*), redness (a*) and yellowness (b*) for beef brisket, eye round and topside measured after blooming for 30 minutes

Week	Brisket		Eye Round		Topside	
L*	x	se	x	se	x	se
1	33.68	± 19.45	41.02	±23.68	38.84	±22.42
4	36.70	±21.19	42.01	±24.25	40.42	±23.34
8	33.66	±19.43	37.70	±21.77	34.27	±19.79
12	34.91	±20.16	38.46	±22.20	40.05	±23.12
16	32.54	±18.79	39.79	±22.97	33.82	±19.53
20	35.68	±20.60	42.31	±24.43	37.18	±21.47
24	38.34	±22.14	35.39	±20.43	40.83	±23.58
28	30.07	±17.36	NT	NA	33.61	±19.40
32	31.23	±18.03	NT	NA	27.14	±15.67
a*						
1	23.80	± 13.74	19.42	±11.21	26.00	±15.01
4	21.91	±12.65	19.48	±11.25	25.57	±14.76
8	22.15	±12.79	20.19	±11.66	19.25	±11.11
12	23.57	±13.61	20.89	±12.06	24.92	±14.39
16	24.38	±14.08	18.88	±10.90	21.20	±12.24
20	23.72	±13.70	18.96	±10.94	23.57	±13.61
24	23.32	±13.46	19.31	±11.15	20.75	±11.98
28	18.15	±10.48	NT	NA	19.59	±11.31
32	16.62	±9.60	NT	NA	16.85	±9.73
b*						
1	1.13	± 0.65	2.42	±1.40	5.98	±3.45
4	1.85	±1.07	2.76	±1.59	5.16	±2.98
8	1.11	±0.64	1.24	±0.72	-1.18	-0.68
12	1.13	±0.65	1.62	±0.93	5.10	±2.94
16	0.84	±0.48	1.38	±0.80	-1.09	-0.63
20	1.42	±0.82	2.46	±1.42	2.38	±1.37
24	2.85	±1.65	-2.04	-1.18	3.56	±2.05
28	1.01	±0.59	NT	NA	1.62	±0.94
32	0.75	±0.43	NT	NA	-0.99	-0.57

Table 1.4. Mean scores for meat aroma, other aroma, liking aroma, meat flavour, other flavour, liking flavour, meat ternderness, meat juiciness and liking overall for vacuum packaged brisket, eye round and topside stored for up to 32 weeks

Week	Muscle	Meat aroma	Other aroma	Liking aroma	Meat flavour	Other flavour	Liking flavour	Meat tenderness	Meat juiciness	Liking overall
0	PP	5.35	2.09	5.63	6.18	1.64	5.72	3.22	5.61	4.41
4	PP	5.35	2.27	4.72	6.22	2.25	5.07	3.30	5.15	3.96
8	PP	5.28	1.74	5.14	6.01	1.76	5.11	3.15	5.11	3.83
12	PP	5.99	1.39	5.82	6.40	1.71	5.24	2.37	5.57	3.24
16	PP	5.40	1.91	5.20	6.34	2.21	5.37	3.39	5.64	4.61
20	PP	5.43	2.73	4.81	6.00	2.11	4.82	3.96	5.91	4.31
24	PP	5.01	3.05	4.18	5.08	4.93	2.84	3.04	5.48	2.51
28	PP	5.21	3.24	3.92	5.62	4.39	3.14	2.95	5.12	2.86
32	PP	5.08	2.83	3.94	5.74	4.16	3.03	3.09	5.47	2.72
0	SM	5.35	2.54	4.63	6.20	1.86	5.61	4.24	5.40	4.92
4	SM	5.38	2.19	5.23	6.66	1.26	6.24	6.13	5.39	5.93
8	SM	5.74	1.76	5.62	6.41	0.95	6.61	6.68	6.38	6.62
12	SM	5.15	2.64	4.73	5.94	2.63	5.19	5.67	4.52	5.00
16	SM	5.74	1.84	5.53	6.36	2.26	5.45	5.70	4.72	5.15
20	SM	5.90	1.87	5.44	6.62	2.13	5.95	5.95	5.30	5.77
24	SM	5.50	2.02	5.32	6.19	2.31	5.64	6.60	4.97	5.22
28	SM	5.10	2.70	4.72	5.81	3.66	4.36	6.58	4.93	4.42
32	SM	5.05	2.70	4.49	5.55	5.53	2.57	5.75	4.08	2.70
0	ST	5.51	1.65	5.80	5.80	1.88	5.03	4.01	6.15	4.60
4	ST	5.79	1.11	5.69	5.87	1.33	5.36	3.58	6.02	4.64
8	ST	5.64	1.53	5.48	6.16	1.63	5.53	4.87	5.11	5.00
12	ST	5.26	1.84	5.41	5.37	2.58	5.00	4.86	5.86	4.90
16	ST	5.60	2.47	5.88	6.32	1.93	5.75	5.09	5.86	5.44
20	ST	5.65	1.87	5.57	6.31	2.03	5.24	6.16	5.83	5.38