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Shelf-life of chilled vacuum packed beef

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1. EXECUTIVE SUMMARY

Vacuum packaging of beef and lamb under chilled conditions remains an effective measure for extending the shelf life of such products and for the control of food borne pathogens. The low oxygen concentration involved in vacuum-packaging has a selective effect on the microbial population and generally results in the proliferation of lactic acid bacteria (LAB).

A previous project (A.MFS.0132) found that shelf-life could be much longer than had previously been documented. While organoleptic assessment was very positive in supporting shelf-life claims, microbiological data were somewhat variable, somewhat lower than expected in many cases, and were considered to be weak in terms of statistical confidence. This project extends that work to a greater number of samples from a greater number of participating processors.

Product scored highly for all sensory evaluations up to and beyond 20 weeks of storage. Between 20 and 30 weeks, there was a gradual decline in scores given for visual appearance, and more marked development of confinement odour. Microbiologically, counts of TVC and LAB increased slowly over the storage period, and the expected plateau at 3 weeks of storage was not evident. The mean TVC on day zero ranged from 1.53 to 4.07 $\log_{10}$ cfu/cm^2, from 2.30 to 5.45 $\log_{10}$ cfu/cm^2 at week 8, from 3.24 to 6.32 $\log_{10}$ cfu/cm^2 at week 20, and 3.48 to 7.65 $\log_{10}$ cfu/cm^2 at week 30. In general, LAB counts mirrored TVC, but the range in mean counts detected was more marked. On day zero, LAB counts were between -0.46 and 1.69 $\log_{10}$ cfu/cm^2, at week 8 between 1.88 and 5.08 $\log_{10}$ cfu/cm^2, 1.38 and 6.25 $\log_{10}$ cfu/cm^2 at week 20, and 1.43 and 6.63 $\log_{10}$ cfu/cm^2 at week 30. More interestingly, there were noticeable differences in the rate of development of the microflora between individual processors, mirroring the differences suggested by project A.MFS.0132. It appeared that the rate of development of LAB in product from processors A, B and E was faster than in product from processors C, D and F, which compares with the findings in A.MFS.0132 that the development of LAB was faster in product from processors B and E than in product from processors C and D.

In terms of taste evaluation in the later stages of storage, in some product, an aged, cheesy or metallic flavour and aftertaste was noticed, but overall the product was considered acceptable, even at week 30.

The data generated by this project support the findings that vacuum packed primals from Australian export processors can be stored confidently for 26 weeks or more, under appropriate conditions. Nevertheless, initial microbial load and strict temperature control will remain critical influences on overall product quality.

2. INTRODUCTION

Vacuum packaging of beef and lamb under chilled conditions remains an effective measure for extending the shelf life of such products and for the control of foodborne pathogens. The low oxygen concentration involved in vacuum-packaging has a selective effect on the microbial population and generally results in the proliferation of lactic acid bacteria (LAB). The predominant organisms include *Carnobacterium divergens*, *Carnobacterium piscicola*, *Lactobacillus sakei*, *Lactobacillus curvatus*, *Leuconostoc gelidum*, *Leuconostoc carnosum* and *Brochothrix thermosphacta* (Fontana et al., 2006, Sakala et al., 2002, Jones, 2004, Ercolini et al., 2006, Nissen and Sorheim, 1996). Under good processing and packaging conditions, the counts of LAB on the surfaces of primals at the time of packaging are very low (<100/cm^2), however the numbers of LAB increase during chilled storage and can be expected to exceed 10^6/cm^2 after 2 to 3 weeks (Leisner et al., 1995, Blixt and Borch, 2002). The presence of high numbers of LAB may result in the presence of unacceptable odours and flavours in products stored for prolonged periods of time (Leisner et al., 1995, Borch et al., 1996). Similarly the presence of LAB and other contaminating bacteria such as *Enterobacteriaceae* may subsequently cause spoilage, odour and flavour issues in retail packs prepared from vacuum-packaged meat.

Despite the industry's continued use of vacuum-packaging as a mechanism for extending shelf-life there has been little recent emphasis on determining factors affecting the storage life of vacuum-packaged beef and lamb and the retail life of meat cuts prepared from the vacuum packs. Consequently current practices are based on data generated up to 2 decades ago. Several requests have come from the market regarding data to support shelf life claims. Improvements in processing technologies, transport and refrigeration systems, and packaging technologies during that time highlights the need for a review of this area. Furthermore, there is an opportunity to generate data that is suitable for incorporation into predictive models which would assist the Australian industry.

In a previous project (A.MFS.0132), four processors provided vacuum packed striploin and cube roll for evaluation of shelf-life. The primals all performed well in terms of colour stability, sensory panel assessment and lipid oxidation measurements over a vacuum storage period of 20 weeks in the formal trial. Excess product was also evaluated at 30 weeks post production, and again found to be acceptable to consumers. In terms of microbiology, some surprising results were obtained: very low counts of aerobic mesophiles and LAB were detected on some product items in the later stages of the trial. Also, there was a large variability in counts between processors and product at any particular time point.

Unfortunately this study only involved a very small number of samples – a single striploin and cube roll from each processor was sampled on each occasion. Bearing in mind the small number of packs sampled and the small number of processors involved, the surprisingly low counts recorded may have been an artefact of the study. However, if this was not the case, it would be very important to understand what has changed in meat processing over the past 20 years in order to achieve these low counts and exceptional storage lives.

The current project aims to verify the storage life outcomes of vacuum packed beef under optimal conditions previously observed in project A.MFS.0132, and to generate data suitable for incorporation into a predictive model to assist the entire industry in setting realistic shelf life claims.

3. PROJECT AIMS

Determine the shelf-life of vacuum packs of beef, as determined by sensory evaluation of typical products exported to the USA.

Collect microbiological data that may assist in the development of a predictive model for the shelf-life of vacuum-packaged beef primals.

4. METHODS

During the week of 2nd to 7th February 2009, day-zero rinse samples were collected on site at each of the six participating processors (designated A-F). Rinse samples were collected in the following manner: 500 ml of sterile 0.85% saline was added to each stomacher bag and the primal massaged on all surfaces for 2 minutes. 200 ml of the resultant rinsate was then decanted into a sterile plastic jar for transport to the laboratory. All rinse samples were delivered that week and early the following week to Food Science Australia (FSA), Cannon Hill, and processed for evaluation of total viable count (TVC) and Lactic Acid bacteria count (LAB). The day-zero counts were subsequently passed to the University of Tasmania (UTAS) to inform the predictive model under development. During the subsequent three weeks, a total of 27 cube rolls and 27 striploins (chilled, vacuum-packed) that had been packed on the relevant 'day zero' were supplied under refrigeration to FSA and stored at -0.5°C ±1.

Three striploins and three cube rolls from each processor were removed from storage on weeks 8, 12, 16, 20, 24, 26, 28 and 30, and subjected to sensory evaluation and microbiological evaluation as follows: packs were assessed by a 6-member informal sensory panel, using a 9-point scale (Appendix A), for vacuum integrity; appearance of the intact pack; presence of confinement odour; and post-bloom appearance, 30 minutes after the pack was opened. Packs were weighed and measured prior to opening, and subsequently the exposed primal transferred to a large stomacher bag and re-weighed to gain an indication of the amount of drip lost. A rinse sample was then collected from each primal as described previously. A decimal dilution series was prepared from each rinse sample in 0.85% saline, and these plated onto Petrifilm Aerobic® and STAA plates for TVC and *Brochothrix thermosphacta* count respectively. The dilutions were also prepared in MRS broth and plated onto Petrifilm Aerobic® according to the Petrifilm method for enumeration of Lactic Acid Bacteria. Petrifilm Aerobic® were incubated aerobically at 25°C ± 1°C for 72 ± 3h; STAA plates were incubated aerobically at 22 ± 1°C for 48 ± 3h; one set of LAB films were incubated anaerobically using Anaerogen W-Zip kits at 25°C for 120 ± 3h, while a second set were incubated aerobically at 25°C for 120 ± 3h.

The dimensions of each primal were used to estimate the surface area sampled, so that microbial counts could be converted to $\log_{10}$cfu/cm², and the mean log of the three samples was calculated using an Excel spreadsheet (Microsoft). When counts on primals were below detectable levels, the mean was taken of the counts on those primals containing enumerable levels.

From week 24 onwards, at each sample point, two representative steaks were cut from the middle of one striploin and one cube roll from each processor. These were sliced into steaks, vacuum packaged and stored at 3-5°C for consumer evaluation within 3 days. The samples were trimmed of excess fat and cooked on a SILEX® Type 610.80, 240V, 2.0kW, DVE and Geprüfte Sicherheit, Germany set at 240°C for 8 minutes. The samples were

turned at 4 minutes (the lid was up for the first 6 minutes and down for the final 2 minutes). The steaks were cooked to a 'medium-rare' level of doneness. The steaks were then rested for 1 minute prior to slicing 15mm cubes for presentation to the consumer panellists. The samples were first placed in polyethylene bags then into polystyrene containers and covered with aluminium foil to keep warm until presented to panellist. The samples were coded and pairs randomly presented monadically to the panellist under daylight conditions. Six samples were presented per session with two sessions conducted at each timepoint for the striploin or cube roll muscles. The samples were evaluated for meat aroma, other aroma, meat flavour, other flavour and overall acceptability using the 9 point category scale with panellists also asked to comment on any flavours detected (Appendix B). On average ten consumers who ate meat regularly attended each of the eight sessions, water was available to cleanse the palate between tastes.

5. RESULTS

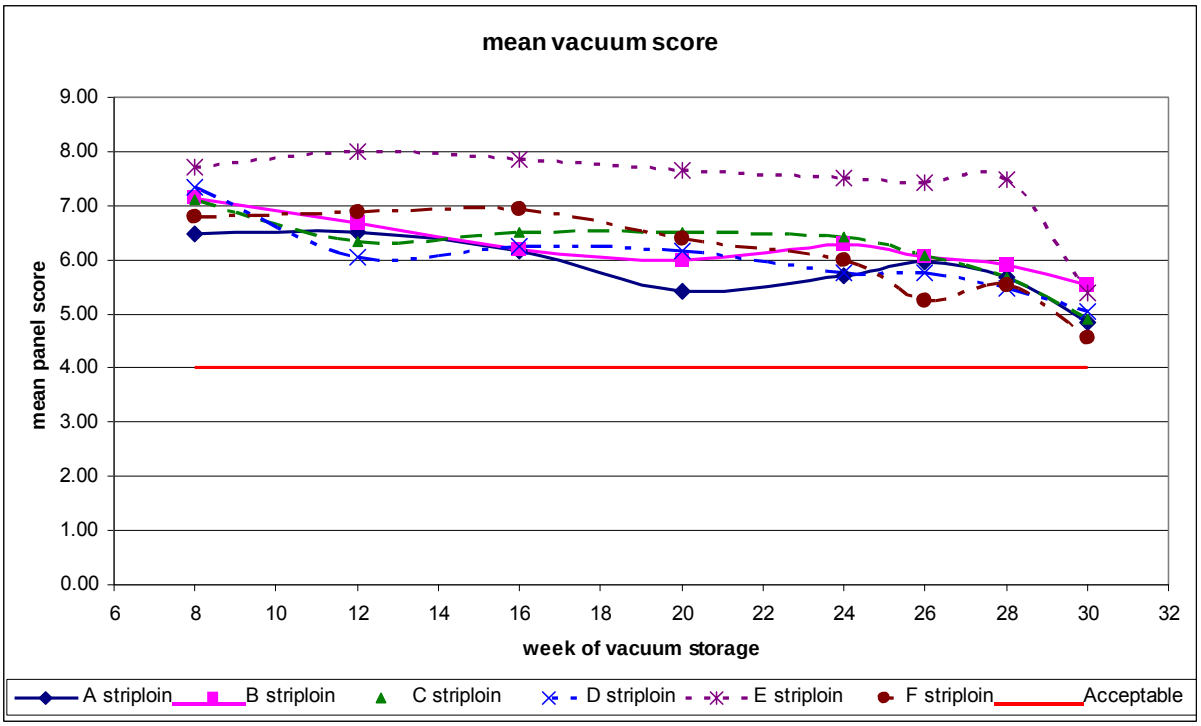
5.1 Sensory Evaluation

Packs scored highly throughout the study in terms of vacuum integrity (figure 1). The volume of drip present in the bags gradually increased during storage, so that in the latter weeks of the study, the packs were considered to be less tight on the primal. Processor E used dripkeepers in the package, so consistently scored slightly higher than other processors.

Visual appearance of packs also scored highly, with a gradual decline until week 26, after which there was a more marked deterioration in the majority of cases (figure 2). Cube roll seemed to maintain the standard of visual appearance to a greater extent than striploin, except for product from processor A. Interestingly, this processor wrapped cube rolls in multiple layers of a cling-wrap type film prior to vacuum packaging. Drip was observed to become trapped between the layers of wrapping, and this had browned, leading to the lower scores being given.

The development of confinement odour occurred slowly over the first 20 weeks of storage, except from processor A striploin, in which confinement odour was more evident from week 12 onwards (figure 3). Striploins generally developed a more noticeable confinement odour than cube rolls, and this was most marked at week 24. However, during the 20-minute bloom period, these odours dissipated. Following week 24, confinement odour scores could be described as marginal in most cases, and unacceptable in some – particularly in product from processor B. The odours were described as 'sweet' or 'cheesy'. Also, in week 28 and in particular week 30, some persistence of odour was noted post bloom from some primals.

Post bloom visual appearance scored highly, with a slight gradual decline, until week 28 (figure 4). The decline in score between week 28 and week 30 was then more marked, particularly in striploin.



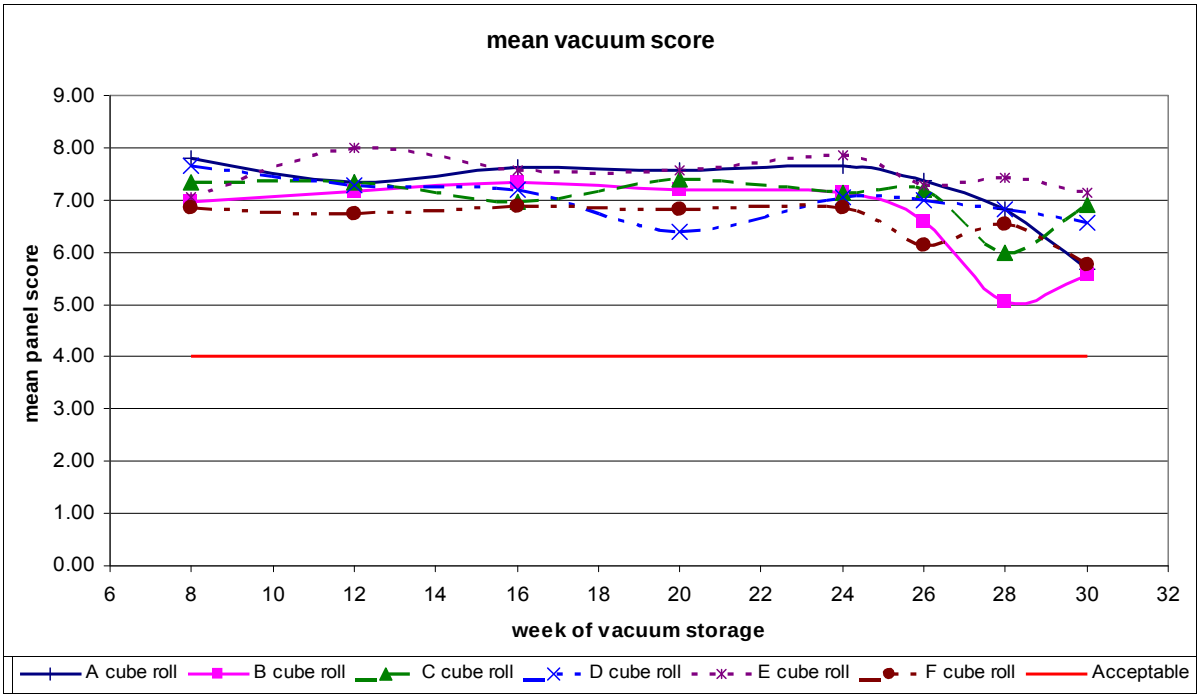
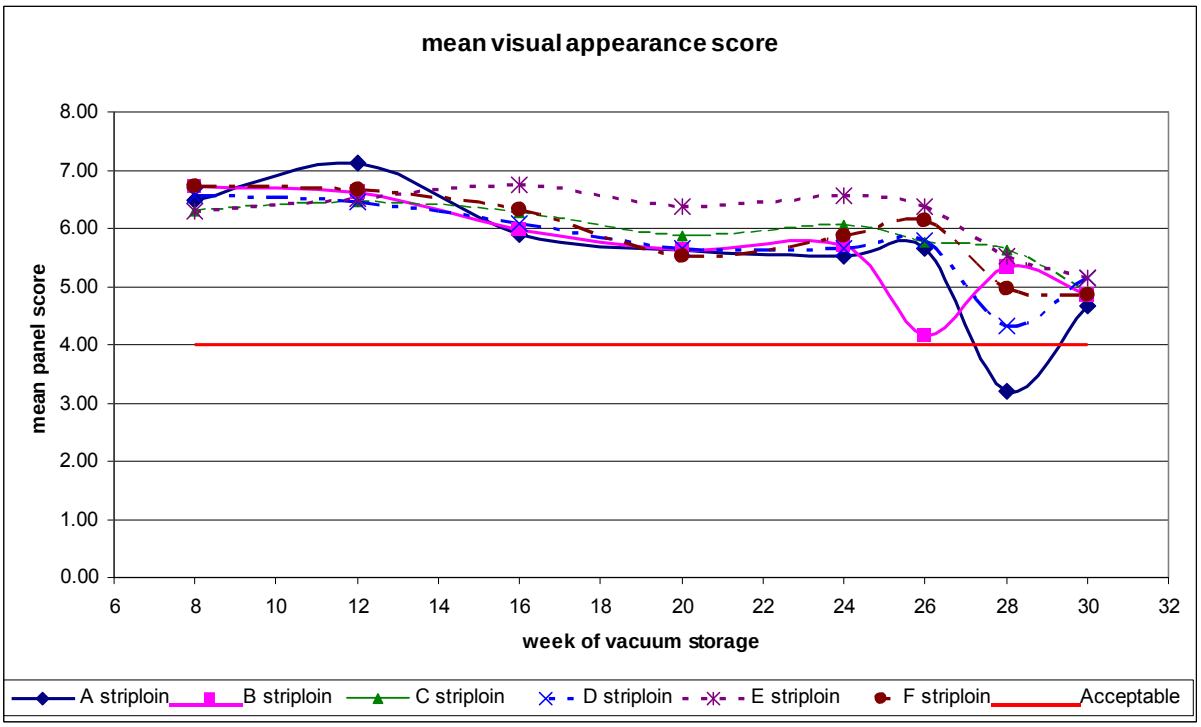


Figure 1: Mean panel score for vacuum integrity, top – striploins, bottom – cube rolls; scoring key – 0 is unacceptable, 4 acceptable or normal, 8 is excellent; tabulated data presented in appendix C



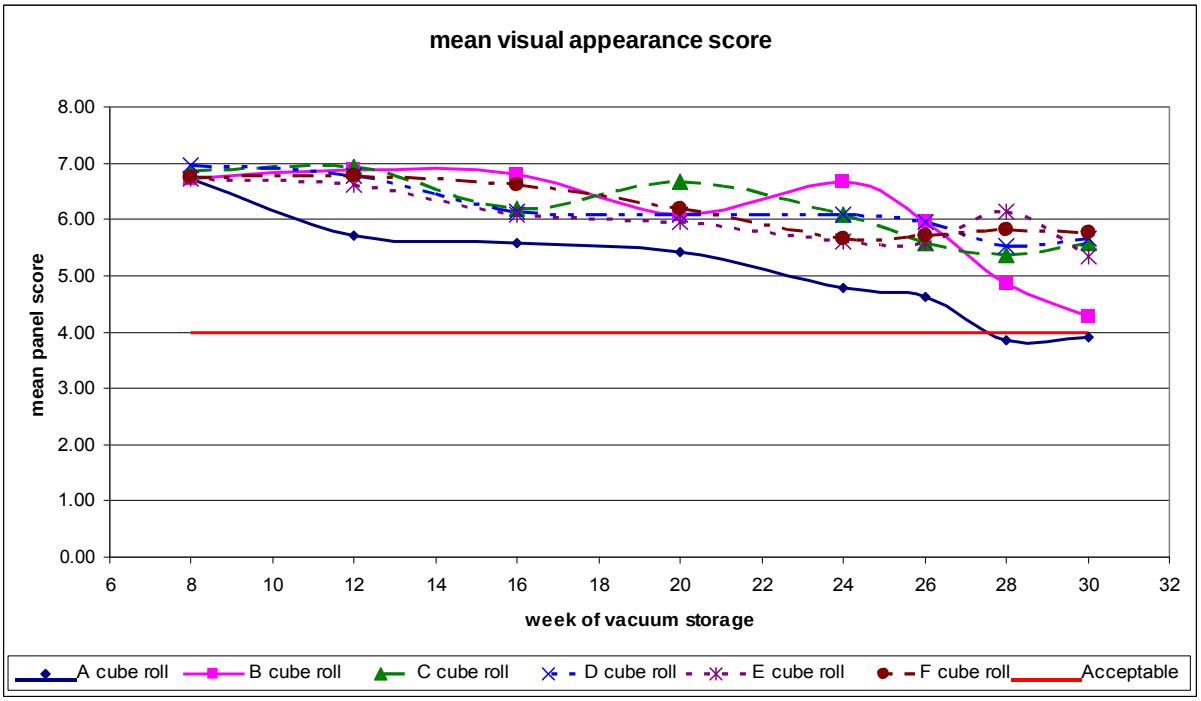
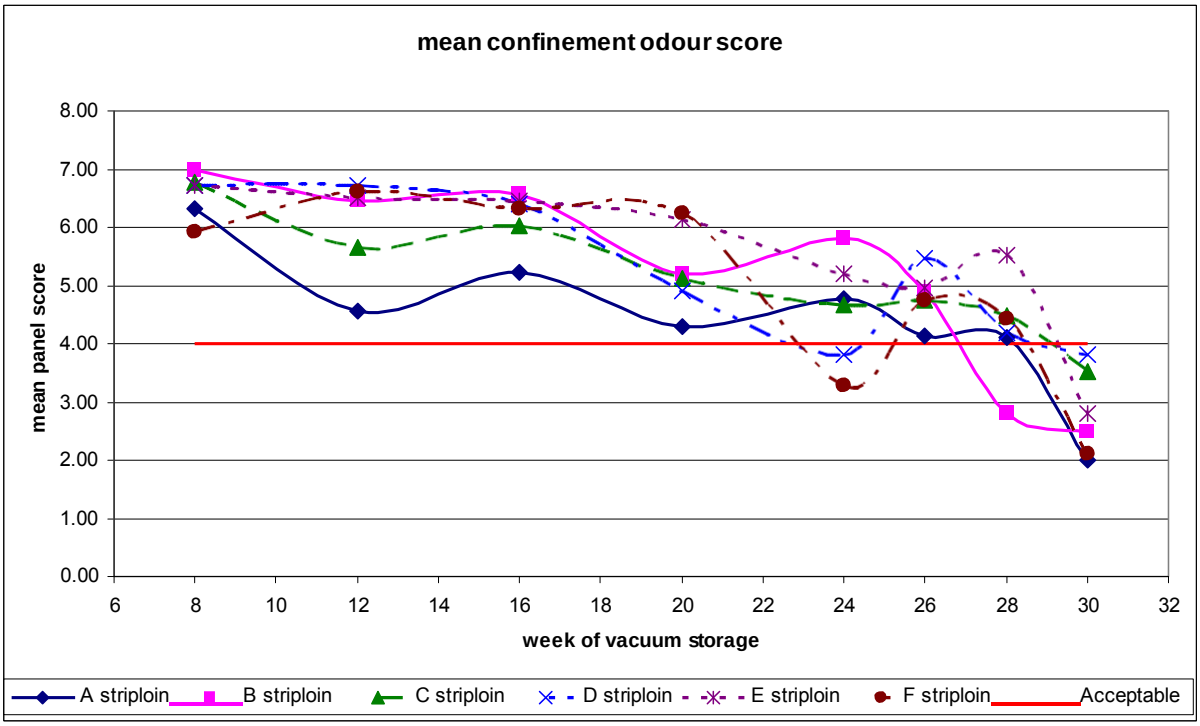


Figure 2: Mean panel score for appearance of intact pack, top – striploins, bottom – cube rolls; scoring key – 0 is unacceptable, 4 acceptable or normal, 8 is excellent; tabulated data presented in appendix C



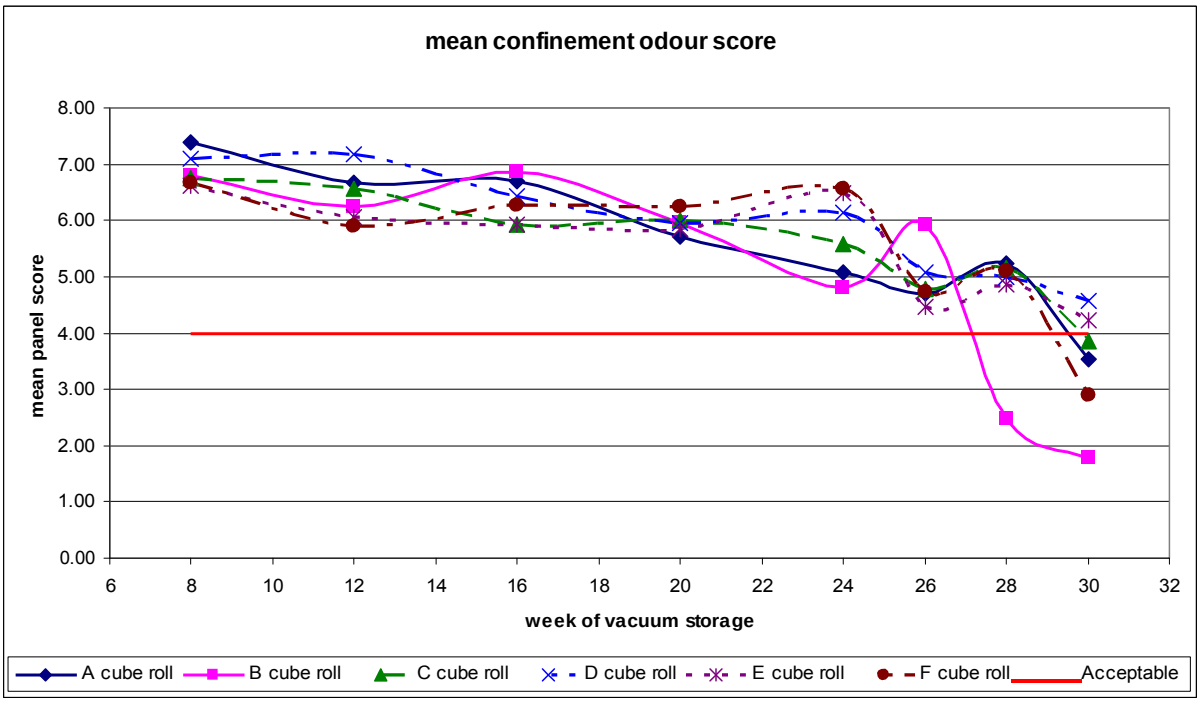
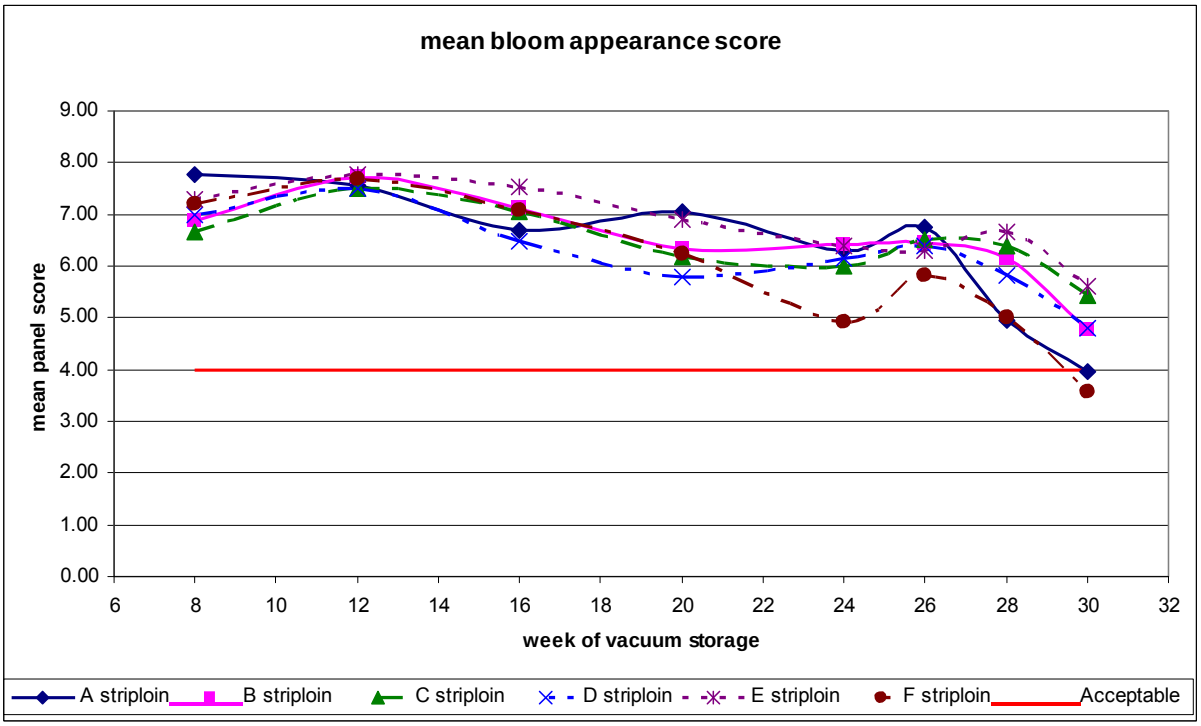


Figure 3: Mean panel score for confinement odour, top – striploins, bottom – cube rolls; scoring key – 0 is unacceptable, 4 acceptable or normal, 8 is excellent; tabulated data presented in appendix C



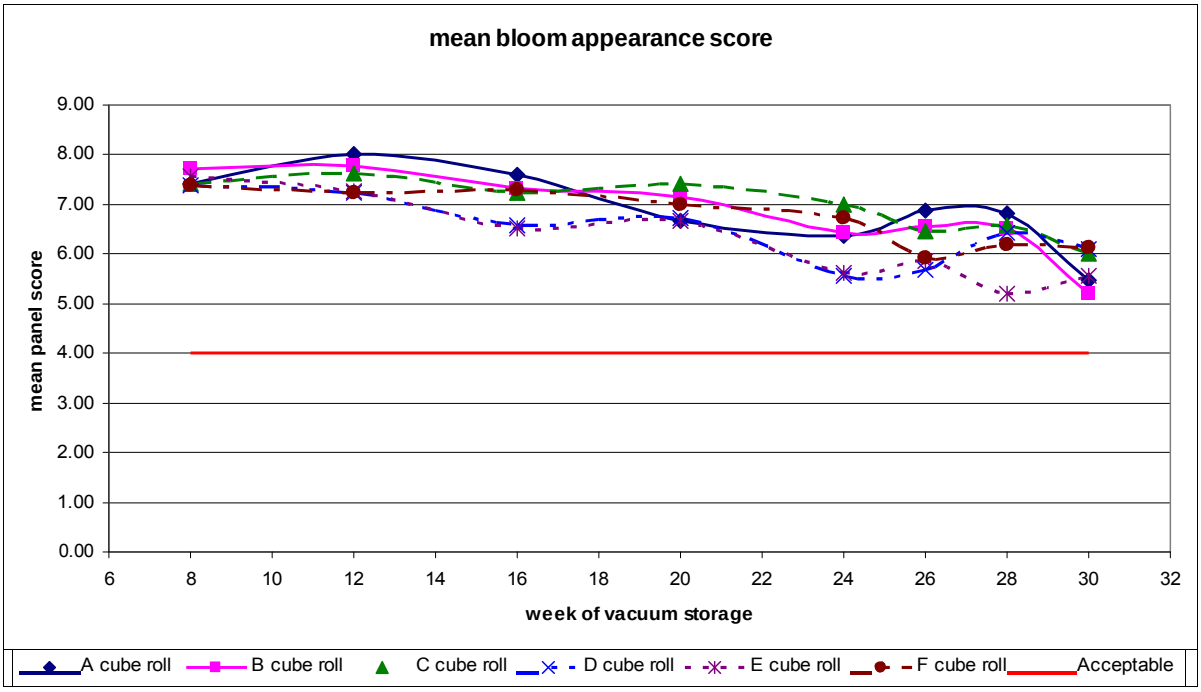


Figure 4: Mean panel score for post bloom visual appearance, top – striploins, bottom – cube rolls; scoring key – 0 is unacceptable, 4 acceptable or normal, 8 is excellent; tabulated data presented in appendix C

5.2 Microbiology

5.2.1 TVC

From published literature, the microbial load of vacuum packaged meat would be expected to increase to a plateau of around 6 $\log_{10}$ cfu/cm^2 after 2 to 3 weeks (Leisner et al., 1995, Blixt and Borch, 2002), and this would be predominantly made up of LAB. In the current study, however, the TVC of primals rose much more slowly (table 1), and counts below 6 $\log_{10}$ cfu/cm^2 were commonly found throughout the storage period. The day zero mean counts differed quite markedly, but, apart from Processor F, were in the range of 1.5 – 3 $\log_{10}$ cfu/cm^2, which was consistent with expectations.

From the mean TVC results at each time point, it appeared that there were differences between the rates of increase between primals and processor, so the triplicate primal counts were used to generate growth curves as shown in figures 6 and 7. Interestingly, these curves were exponential rather than showing plateau formation, as would be expected from literature. In striploins (figure 5), processors C, E and, particularly, F showed slower growth rates than processors A, B and D. Processor F, however, had a large variation in the counts at each time point, so the curve generated may not be reliable – the goodness of fit (R^2 value) was only 0.2472 (table 1). The R^2 values for processors C and E, in comparison, were 0.4763 and 0.612 respectively – moderate to good fit. In cube rolls, it appeared that the growth of microflora in processor B product was the fastest (figure 6), and that of processors D and F slowest. Once again, however, there was great variability in the counts from processor F (R^2 value 0.0998). Overall the goodness of fit for cube roll TVC growth curves was moderate at best (table 3), except in processor E (R^2 value 0.682).

Table 1: TVC ($log_{10}cfu/cm^2$)

sample	week 0	week 8	week 12	week 16	week 20	week 24	week 26	week 28	week 30
A striploin	1.74 (0.11)*	5.04 (1.08)	6.34 (0.67)	6.45 (0.97)	5.51 (0.40)	6.28 (0.38)	6.59 (0.34)	7.34 (0.42)	7.17 (0.43)
B striploin	1.53 (0.41)	4.00 (1.29)	4.53 (1.18)	4.83 (0.10)	4.80 (0.99)	3.79 (0.22)	5.86 (0.96)	4.27 (1.20)	6.10 (0.87)
C striploin	2.20 (0.38)	2.30 (0.80)	3.90 (0.10)	4.04 (0.20)	4.79 (0.31)	4.18 (0.86)	4.83 (0.17)	3.71 (2.06)	5.96 (0.53)
D striploin	1.98 (0.39)	3.80 (0.32)	3.91 (0.46)	4.03 (0.26)	4.55 (0.91)	6.41 (0.28)	5.95 (0.54)	5.77 (0.39)	6.13 (1.03)
E striploin	2.54 (0.48)	4.53 (0.42)	4.63 (0.14)	5.79 (0.37)	4.64 (0.37)	5.29 (0.67)	6.02 (0.60)	5.13 (0.35)	5.97 (0.08)
F striploin	3.34 (0.41)	2.59 (1.77)	3.31 (0.61)	4.32 (0.22)	3.98 (1.72)	5.17 (0.68)	6.06 (1.60)	6.05 (0.62)	3.48 (0.64)
A cube roll	1.99 (0.19)	4.52 (1.23)	4.05 (0.92)	6.21 (0.17)	4.31 (0.14)	5.96 (0.57)	4.89 (0.41)	5.33 (0.78)	4.69 (0.55)
B cube roll	1.68 (0.27)	4.79 (0.89)	4.35 (1.16)	5.01 (1.25)	5.81 (1.38)	4.88 (0.68)	5.96 (0.39)	5.68 (2.76)	7.65 (0.58)
C cube roll	2.66 (0.08)	3.50 (0.47)	1.64 (0.18)	3.00 (1.65)	4.55 (0.21)	6.18 (0.34)	3.26 (0.96)	5.01 (1.24)	5.62 (0.38)
D cube roll	2.54 (0.29)	2.59 (0.22)	2.56 (1.21)	2.87 (1.20)	3.24 (0.80)	2.97 (0.31)	5.48 (0.90)	3.56 (0.94)	5.48 (1.12)
E cube roll	2.55 (0.13)	3.63 (0.62)	5.33 (0.82)	5.50 (0.98)	6.32 (0.47)	4.99 (0.74)	5.84 (0.77)	6.18 (0.36)	6.48 (0.23)
F cube roll	4.07 (0.37)	5.45 (1.21)	5.16 (0.79)	4.23 (0.77)	5.53 (0.81)	3.90 (0.32)	4.39 (0.43)	5.49 (0.86)	6.94 (0.26)

*Mean log_{10} cfu/cm² with standard deviation in parenthesis

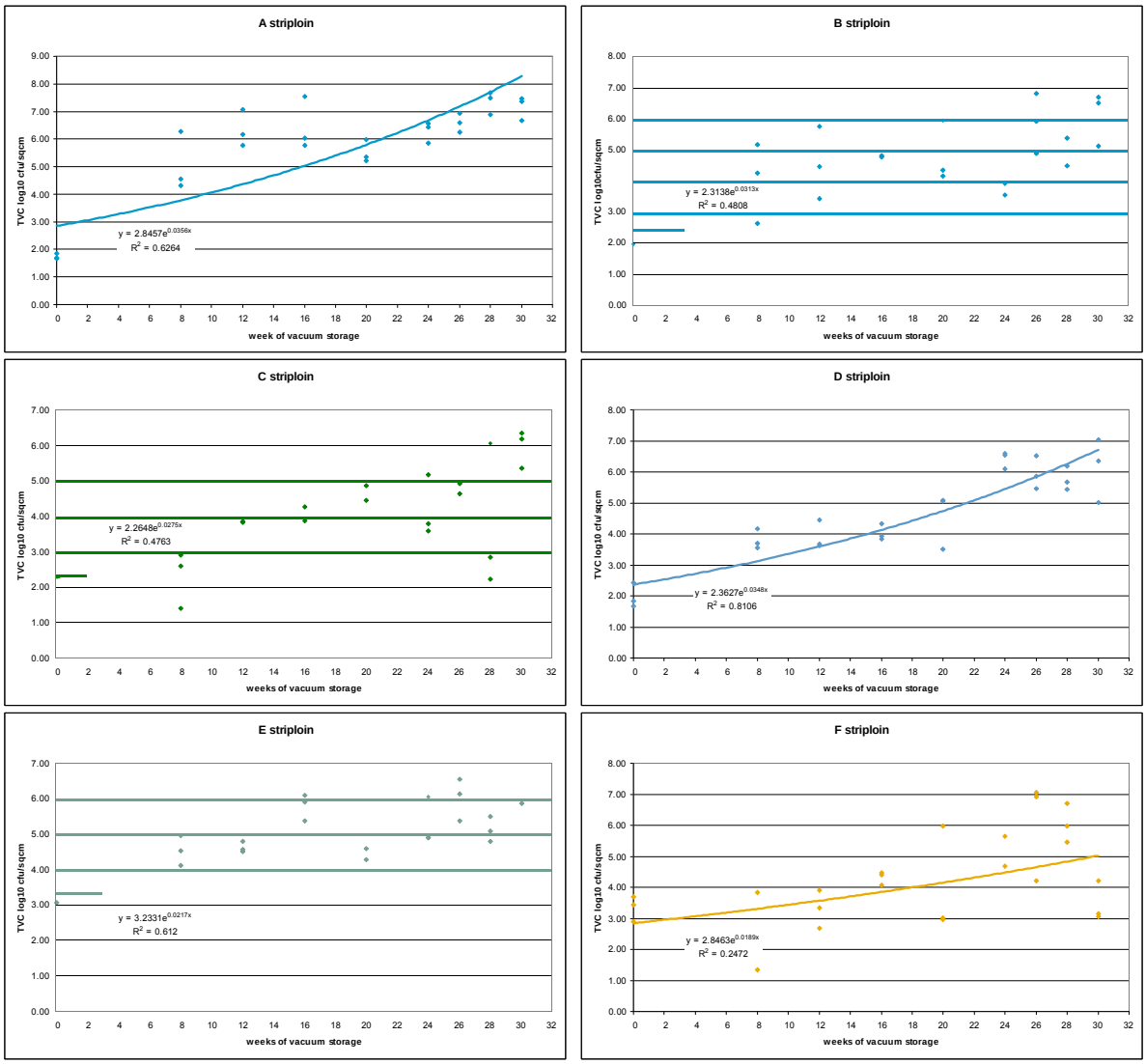


Figure 5: Development of total microflora on striploins over 30 weeks storage

Table 2: Linear equations associated with trend lines shown in figure 6

Sample	Linear equation	R² value
A striploin	$y = 2.8457e^{0.0356x}$	0.6264
B striploin	$y = 2.138e^{0.0313x}$	0.4808
C striploin	$y = 2.2648e^{0.0275x}$	0.4763
D striploin	$y = 2.3627e^{0.0348x}$	0.8106
E striploin	$y = 3.2331e^{0.0217x}$	0.612
F striploin	$y = 2.8463e^{0.0189x}$	0.2472

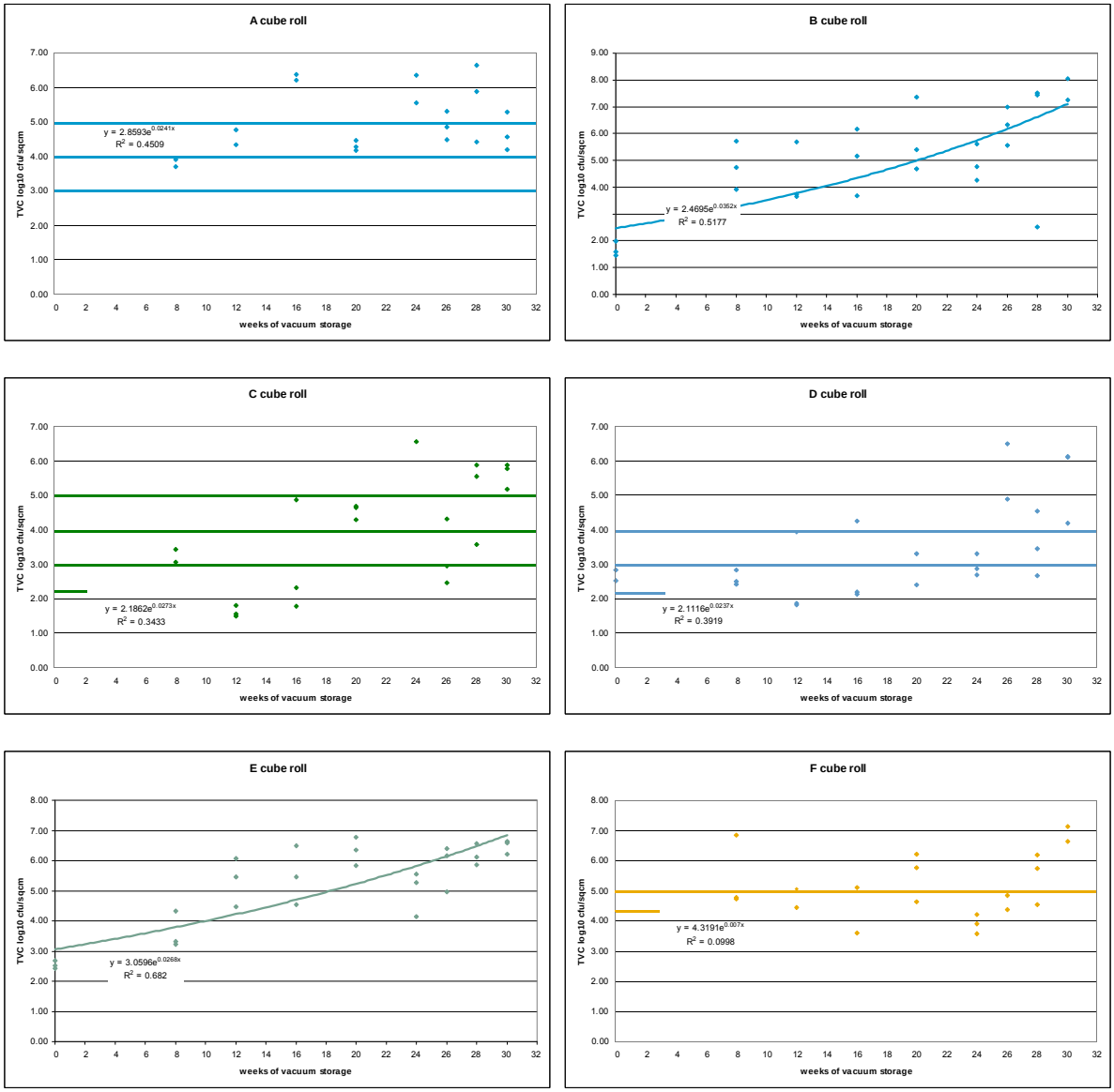


Figure 6: Development of total microflora of cube rolls over 30 weeks of storage

Table 3: Linear equations associated with trend lines shown in figure 7

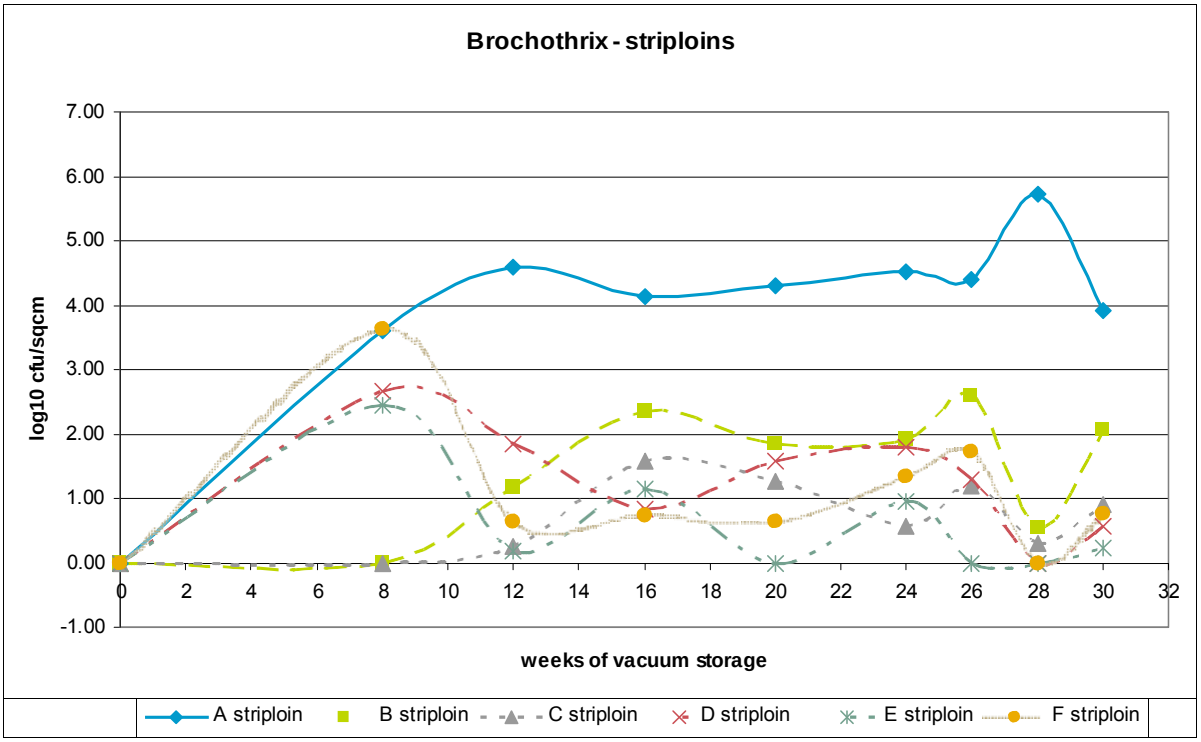
Sample	Linear equation	R² value
A cube roll	$y = 2.8593e^{0.0241x}$	0.4509
B cube roll	$y = 2.4695e^{0.0352x}$	0.5177
C cube roll	$y = 2.1862e^{0.0273x}$	0.3433
D cube roll	$y = 2.1116e^{0.0237x}$	0.3919
E cube roll	$y = 3.0596e^{0.0268x}$	0.682
F cube roll	$y = 4.3191e^{0.007x}$	0.0998

5.2.2 Brochothrix thermosphacta

Brochothrix thermosphacta counts were generally low throughout the study, and detections were sporadic (figure 7), except for in processor A striploin, where counts reached a plateau of between 4 and 5 $\log_{10}$ cfu/cm^2 at around week 12. *Br thermosphacta* is usually associated with meat of higher pH, and it was unfortunate that in this study, the meat pH was not tested at each sampling point.

5.2.3 Lactic Acid bacteria (LAB)

As with TVC, LAB counts would be expected to rise to a plateau of around 6 $\log_{10}$ cfu/cm^2 over the first 2-3 weeks of storage. As with TVC in this study, LAB levels rose slowly during the period of storage, perhaps beginning to plateau in some primal/processor pairs after 12 weeks (table 4). Again it was decided to generate growth curves from the data, and these are shown in figures 8 and 9. There was a lot of variation in the counts, so the R^2 values (tables 5 and 6) for these curves are generally low (below 4), except for striploin processors A, E and F, and cube roll processor E. However, the indication was that growth rates of LAB were higher in product from processors A, B and E, compared with processors C, D and F.



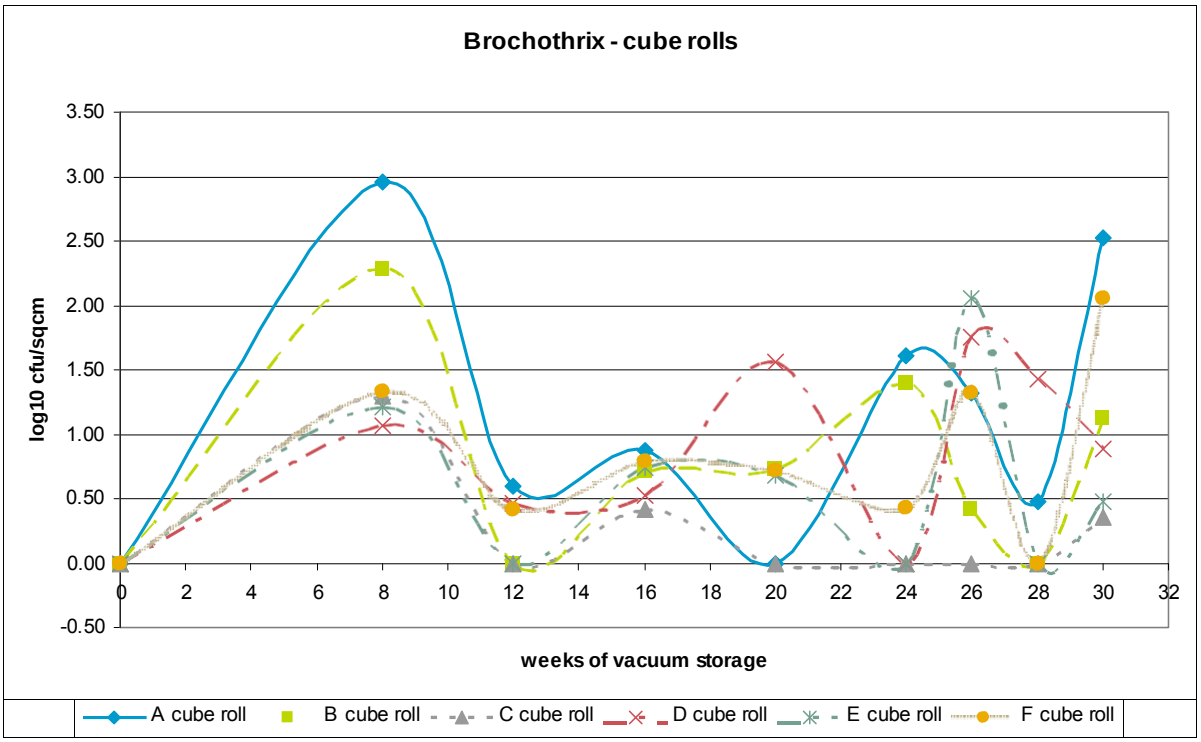


Figure 7: Mean *Brochothrix thermosphacta* count for three primals tested at each sample point; top – striploins, bottom – cube rolls

Table 4: Lactic Acid Bacteria (LAB) count ($log_{10}cfu/cm^2$): anaerobic incubation

sample	week 0	week 8	week 12	week 16	week 20	week 24	week 26	week 28	week 30
A striploin	-0.46 (0.32)	2.60 (2.87)	3.62 (3.73)	5.06 (1.97)	6.25 (0.35)	6.20 (0.47)	6.46 (0.29)	6.72 (0.10)	6.63 (0.20)
B striploin	0.93 (0.20)	4.15 (1.22)	4.67 (1.17)	4.72 (0.16)	5.55 (0.29)	3.42 (0.37)	5.65 (0.94)	2.82 (1.23)	6.00 (0.85)
C striploin	0.94 (0.30)	1.88 (0.18)	3.61 (0.16)	4.02 (0.15)	4.75 (0.24)	2.95 (0.41)	4.35 (0.25)	2.86 (2.01)	2.36 (2.61)
D striploin	0.52 (0.34)	3.80 (0.30)	2.45 (2.69)	4.11 (0.22)	5.02 (1.03)	5.59 (0.75)	5.59 (0.50)	not detected	3.51 (0.81)
E striploin	1.44 (0.29)	2.83 (0.74)	4.60 (0.73)	4.90 (0.46)	5.17 (0.77)	4.35 (0.38)	5.30 (0.43)	3.79 (0.83)	5.91 (0.12)
F striploin	1.45 (0.16)	2.29 (0.86)	3.57 (0.39)	3.50 (0.94)	2.67 (0.17)	5.13 (0.73)	5.91 (1.66)	4.21 (1.43)	4.50 (0.92)
A cube roll	0.71 (0.73)	4.13 (1.02)	4.30 (0.66)	6.11 (0.20)	4.29 (0.26)	5.32 (1.23)	4.46 (0.65)	4.63 (0.94)	4.47 (0.50)
B cube roll	0.53 (0.80)	4.38 (1.15)	4.05 (1.18)	4.69 (1.30)	6.18 (0.80)	4.39 (0.20)	4.71 (1.33)	4.13 (3.16)	7.25 (0.38)
C cube roll	1.01 (0.32)	2.41 (0.65)	-0.01 (0.94)	1.46 (0.32)	1.38 (0.16)	not detected	0.96 (0.29)	2.17 (0.38)	1.43 (1.65)
D cube roll	1.55 (0.34)	2.21 (0.39)	2.09 (1.52)	2.76 (1.25)	3.34 (0.93)	2.26 (2.38)	5.33 (0.88)	3.65 (1.58)	3.52 (3.35)
E cube roll	1.35 (0.31)	3.07 (0.61)	5.11 (0.74)	5.16 (1.03)	5.81 (0.48)	3.90 (0.42)	5.52 (0.03)	5.13 (0.09)	6.39 (0.29)
F cube roll	1.69 (0.15)	5.08 (0.77)	5.11 (0.86)	4.68 (1.26)	6.01 (0.51)	not detected	5.51 (0.18)	4.94 (0.66)	4.95 (1.98)

*Mean log_{10} cfu/cm² with standard deviation in parenthesis

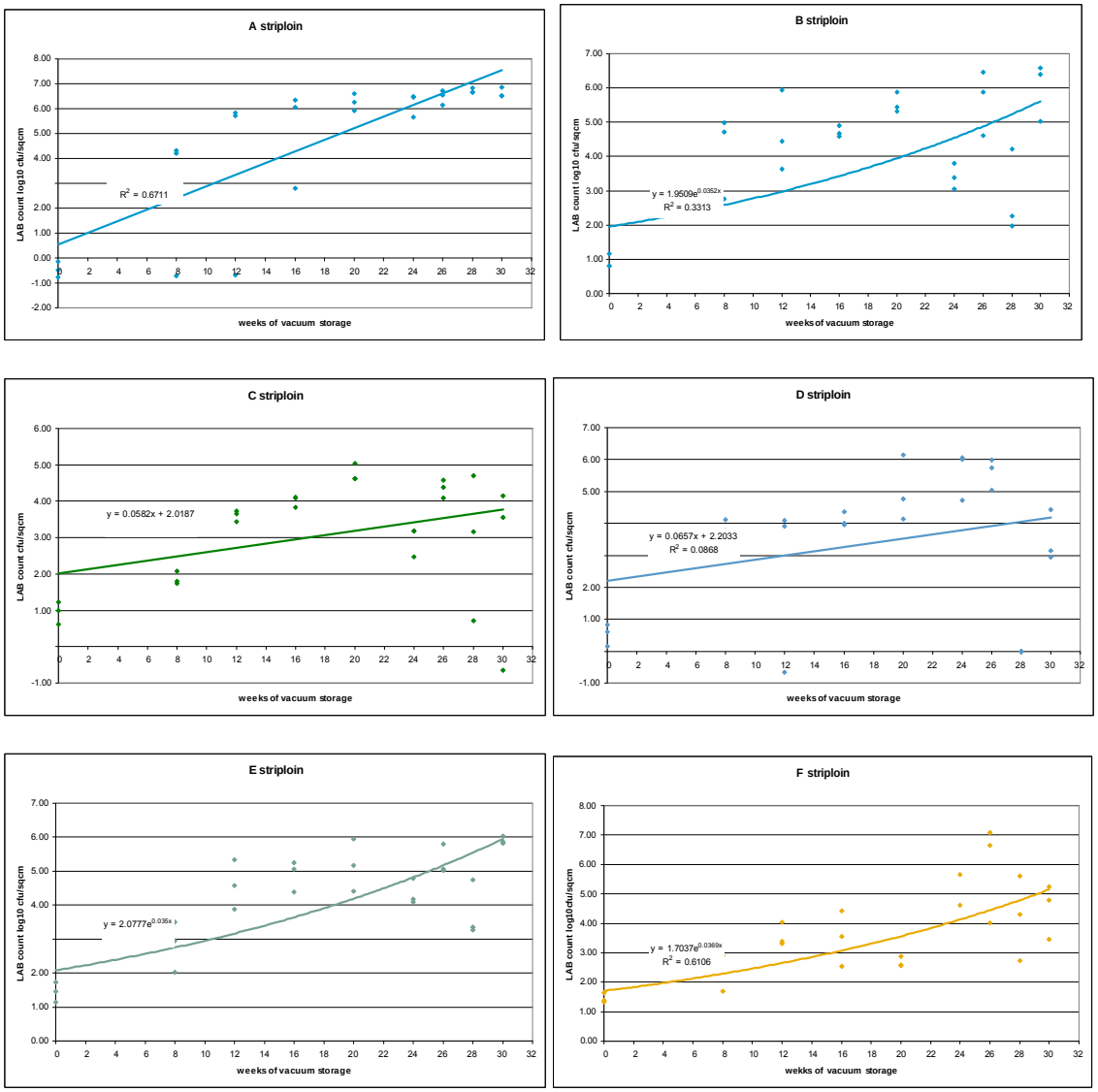


Figure 8: Development of LAB on striploins over 30 weeks of storage

Table 5: Linear equations associated with trend lines shown in figure 10

Sample	Linear equation	R² value
A striploin	$y = 0.233x + 0.54$	0.6711
B striploin	$y = 1.9509e^{0.0352x}$	0.3313
C striploin	$y = 0.0582x + 2.0187$	0.1396
D striploin	$y = 0.0657x + 2.2033$	0.0868
E striploin	$y = 2.0777e^{0.035x}$	0.5769
F striploin	$y = 1.7037e^{0.0369x}$	0.6106

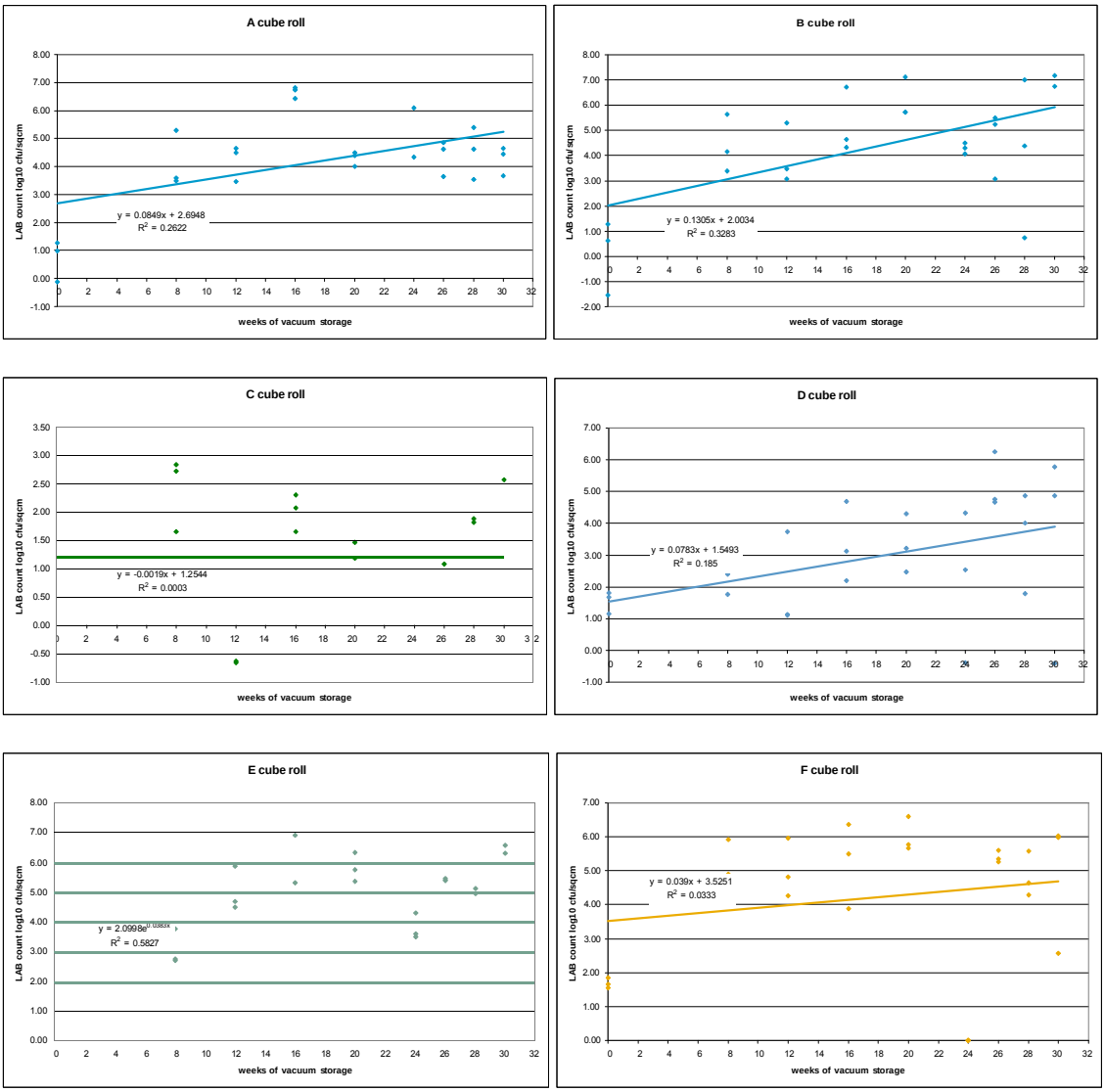


Figure 9: Development of LAB on cube rolls over 30 weeks of storage

Table 6: Linear equations associated with trend lines shown in figure 11

Sample	Linear equation	R² value
A cube roll	y = 0.0849x + 2.6948	0.2622
B cube roll	y = 0.1305x + 2.0034	0.3283
C cube roll	y = -0.0019x + 1.2544	0.0003
D cube roll	y = 0.0783x + 1.5493	0.185
E cube roll	$y = 2.0998e^{0.0383x}$	0.5827
F cube roll	y = 0.039x + 3.5251	0.0333

5.3 Taste Panel Evaluation

The meat aroma for the six processors over the four timepoints was rated as being in the slight to moderate category for the striploin and cuberoll muscles (table 7). Meat flavour was also assessed as being in the slight to moderately strong category for the four timepoints (table 9).

“Other aroma” was rated as very slight to moderate (table 8) with the “other flavour” category rated very slight to moderately strong overall (table 10). The “other flavour” score for processor A striploins was significantly higher at the 28 and 30 week time points than at any other time. The cube roll for processor F at 30 weeks rated moderate to strong for “other aroma” and “other flavour” and was described as sour and acidic at 28 weeks with an aftertaste at 30 weeks (table 12). Processor F was rated as having the highest “other flavour” at the 26, 28 and 30 week timepoints for the cuberoll muscle only. Whereas for this processor the striploin muscle had only slight to moderate other flavours detected.

The overall acceptability for processors C and D striploins rated highest at moderate to good at 30 weeks followed closely by processor E (table 11). Overall, the striploin for processor A was rated lowest at poor to moderate for all timepoints evaluated.

The cuberolls for processors B and D rated highest overall acceptability at the 30 week timepoint and were assessed as being in the ‘good’ category. Processors A and E cuberolls were rated as being moderate to good at the 30 week timepoint.

Table 7: Mean panel scores for meat aroma

	Meat Aroma			
	week 24	**week 26**	**week 28**	**week 30**
A striploin	3.6*	4.0	3.8	4.0
	(1.5)	(1.9)	(1.0)	(1.4)
B striploin	3.9	4.3	4.5	4.6
	(1.1)	(1.0)	(0.8)	(1.5)
C striploin	3.7	3.9	3.9	3.9
	(1.2)	(2.0)	(1.4)	(1.6)
D striploin	3.8	4.7	3.5	4.3
	(1.8)	(1.3)	(1.3)	(0.9)
E striploin	3.0	4.4	3.9	3.8
	(1.4)	(1.6)	(1.6)	(1.5)
F striploin	3.3	3.9	4.0	4.6
	(2.3)	(2.0)	(1.8)	(1.2)
A cuberolls	3.6	3.9	4.8	3.3
	(1.5)	(1.3)	(1.2)	(1.4)
B cuberolls	4.3	4.4	4.3	3.7
	(1.7)	(1.4)	(1.0)	(1.3)
C cuberolls	4.1	4.4	4.6	4.3
	(1.8)	(1.9)	(1.6)	(1.0)
D cuberolls	3.8	4.1	4.4	4.0
	(2.0)	(1.2)	(1.3)	(1.0)
E cuberolls	3.9	5.0	4.4	4.3
	(1.8)	(1.6)	(1.4)	(0.8)
F cuberolls	3.9	4.1	4.5	3.6
	(1.4)	(1.5)	(1.1)	(2.2)

*mean taste panel score with standard deviation in parenthesis below

Table 8: Mean panel score for other aroma

	Other Aroma			
	week 24	**week 26**	**week 28**	**week 30**
A striploin	2.5*	3.4	3.9	4.8
	(1.4)	(2.0)	(2.0)	(1.8)
B striploin	2.3	4.3	3.1	4.3
	(1.8)	(1.6)	(2.1)	(2.1)
C striploin	1.9	3.6	1.8	4.1
	(1.4)	(1.9)	(0.9)	(2.3)
D striploin	2.5	4.1	2.0	4.8
	(1.4)	(2.0)	(0.8)	(1.8)
E striploin	2.3	2.9	2.4	3.8
	(1.4)	(0.7)	(2.0)	(1.5)
F striploin	1.9	2.9	2.1	4.0
	(1.7)	(1.3)	(1.5)	(2.4)
A cuberolls	2.9	2.9	4.6	2.7
	(1.8)	(2.0)	(2.6)	(2.1)
B cuberolls	3.5	3.7	2.9	2.6
	(2.0)	(2.0)	(2.0)	(1.8)
C cuberolls	2.1	4.0	3.0	2.7
	(1.1)	(2.3)	(1.6)	(1.0)
D cuberolls	2.7	3.3	3.8	3.0
	(2.1)	(2.1)	(2.3)	(1.9)
E cuberolls	2.9	3.1	3.3	2.9
	(1.7)	(1.9)	(2.7)	(1.2)
F cuberolls	2.7	4.0	3.3	4.9
	(1.7)	(2.8)	(1.8)	(2.0)

*mean taste panel score with standard deviation in parenthesis below

Table 9: Mean panel score for meat flavour

	Meat Flavour			
	week 24	**week 26**	**week 28**	**week 30**
A striploin	3.7*	5.0	3.5	4.0
	(1.5)	(1.9)	(1.2)	(2.4)
B striploin	5.1	4.9	4.9	4.8
	(0.8)	(0.7)	(1.5)	(1.4)
C striploin	4.9	5.4	3.5	4.1
	(1.5)	(1.9)	(1.6)	(1.5)
D striploin	5.5	5.6	4.6	5.5
	(1.5)	(1.8)	(1.8)	(1.2)
E striploin	4.9	6.0	4.3	4.6
	(1.8)	(1.7)	(1.0)	(1.5)
F striploin	5.0	4.4	4.0	5.3
	(2.0)	(2.4)	(1.9)	(1.2)
A cuberolls	4.3	5.3	4.5	4.1
	(1.6)	(1.3)	(1.2)	(1.7)
B cuberolls	4.9	5.6	3.6	4.4
	(1.6)	(1.0)	(1.3)	(1.6)
C cuberolls	4.8	4.9	4.6	3.9
	(1.6)	(1.1)	(1.3)	(1.6)
D cuberolls	4.1	5.4	4.0	5.1
	(1.5)	(1.5)	(1.1)	(0.9)
E cuberolls	4.6	5.6	4.8	4.6
	(1.4)	(1.4)	(1.3)	(0.8)
F cuberolls	4.9	5.1	4.4	3.1
	(1.8)	(2.0)	(1.1)	(1.3)

*mean taste panel score with standard deviation in parenthesis below

Table 10: Mean panel score for other flavour

	Other Flavour			
	week 24	**week 26**	**week 28**	**week 30**
A striploin	4.0*	3.3	6.3	5.6
	(2.0)	(1.3)	(2.3)	(1.7)
B striploin	2.3	3.7	3.4	4.5
	(1.1)	(1.1)	(1.6)	(2.7)
C striploin	3.3	3.4	3.0	3.4
	(2.2)	(1.4)	(1.5)	(1.8)
D striploin	3.3	4.1	3.9	4.0
	(1.8)	(1.5)	(2.2)	(1.8)
E striploin	2.9	3.6	2.6	3.3
	(1.8)	(1.5)	(1.1)	(1.2)
F striploin	3.8	2.6	3.0	4.3
	(2.4)	(0.5)	(1.8)	(2.0)
A cuberolls	3.7	2.9	3.6	2.4
	(2.0)	(1.9)	(2.0)	(2.2)
B cuberolls	4.0	4.1	3.8	3.3
	(2.0)	(1.7)	(1.4)	(2.4)
C cuberolls	3.2	3.9	3.6	4.0
	(1.7)	(2.3)	(2.1)	(1.7)
D cuberolls	2.7	4.0	3.1	2.6
	(1.6)	(1.9)	(1.4)	(1.6)
E cuberolls	3.0	3.0	3.3	3.0
	(1.7)	(1.2)	(1.9)	(1.2)
F cuberolls	3.5	4.7	3.8	5.7
	(1.80	(1.70	(1.6)	(1.6)

*mean taste panel score with standard deviation in parenthesis below

Table 11: Mean panel score for overall acceptability

	Overall Acceptability			
	week 24	**week 26**	**week 28**	**week 30**
A striploin	4.6*	5.1	4.4	4.0
	(1.7)	(1.7)	(2.6)	(1.6)
B striploin	5.7	5.6	5.8	5.6
	(1.2)	(1.4)	(1.3)	(2.1)
C striploin	5.0	5.4	4.9	6.1
	(1.6)	(1.5)	(1.4)	(1.0)
D striploin	5.7	5.7	5.3	6.1
	(1.9)	(1.5)	(1.6)	(1.9)
E striploin	5.5	6.4	5.5	5.9
	(2.0)	(1.0)	(1.5)	(1.4)
F striploin	5.4	5.9	5.1	5.4
	(2.0)	(2.0)	(1.5)	(1.4)
A cuberolls	4.5	6.1	5.4	5.9
	(1.9)	(1.7)	(1.7)	(2.5)
B cuberolls	5.1	6.3	4.9	6.6
	(1.7)	(1.3)	(1.8)	(1.9)
C cuberolls	5.5	5.7	4.9	5.7
	(1.7)	(2.2)	(1.9)	(1.0)
D cuberolls	5.3	4.9	5.5	6.6
	(1.4)	(1.5)	(1.1)	(0.8)
E cuberolls	4.9	6.6	5.1	5.9
	(1.8)	(1.0)	(1.4)	(1.1)
F cuberolls	5.2	4.0	4.9	4.3
	(1.5)	(1.2)	(1.4)	(2.3)

*mean taste panel score with standard deviation in parenthesis below

Table 12: Consumer panel comments at timepoints evaluated

Processor	Striploin	Cuberolls
Week 24		
A	Metallic, sour	Aftertaste
B		
C	Earthy, aged, sour	
D	Burnt flavour	
E	After taste	Mouldy, eggy
F	Pleasant, sweet, not meat like, grassy	Aftertaste
Week 26		
A	Very Tender, aftertaste	
B	Sour	
C		
D	Sour	
E	Slight metallic	
F		
Week 28		
A		Burnt, sour
B	Sour	Sweetish, dry
C	Vegetable	Metallic
D	Sour	Acidic
E	Sl. Metallic, vegetable	Sour
F		Sour, acidic, acidic taste
Week 30		
A		Sharp
B	Sour	Sweet
C		
D	Sweet	
E		
F	Metallic, sour	Aftertaste

5.4 Correlations

An attempt was made to identify correlations between evaluation parameters, using scatterplots. Weak to moderate ($R^2 \geq 0.3$) positive correlations (figures 10-15) were found between:

- vacuum integrity and intact pack visual appearance ($R^2 = 0.312$);
- vacuum integrity and confinement odour score ($R^2 = 0.3747$);
- intact pack visual appearance and confinement odour score ($R^2 = 0.4284$);
- intact pack visual appearance and bloomed primal visual appearance ($R^2 = 0.4098$)
- bloomed primal visual appearance and confinement odour ($R^2 = 0.4098$)
- TVC and LAB count ($R^2 = 0.3041$)

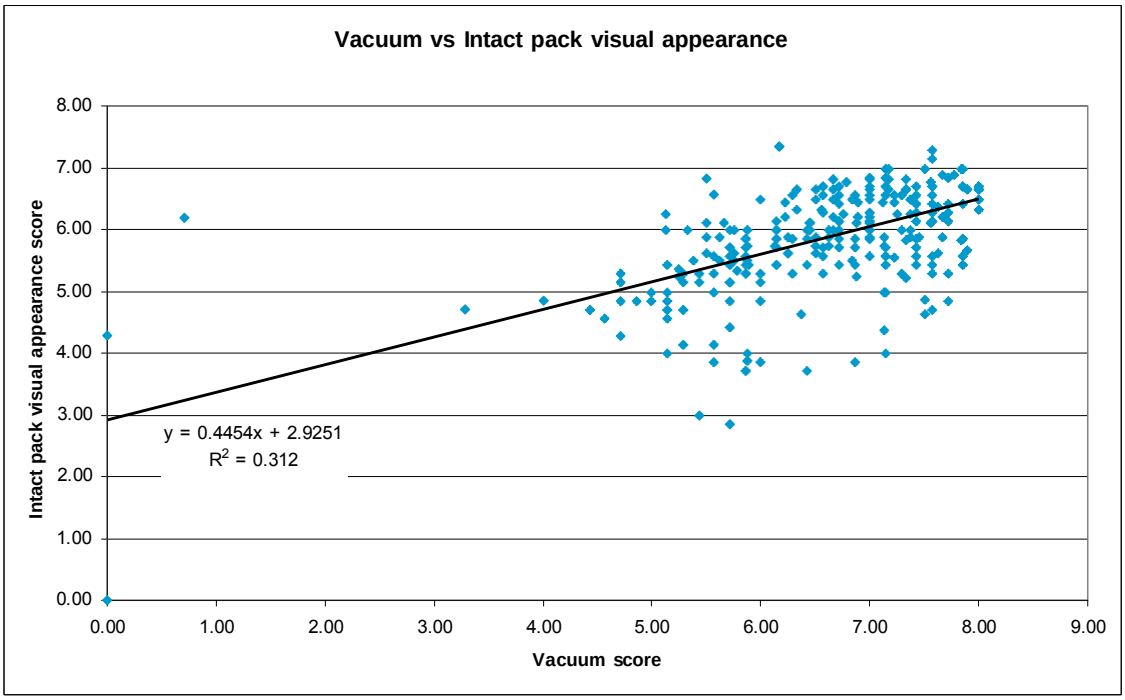


Figure 10: Correlation between vacuum integrity score and visual appearance of intact pack score: both scales 0 is unacceptable, 8 is excellent.

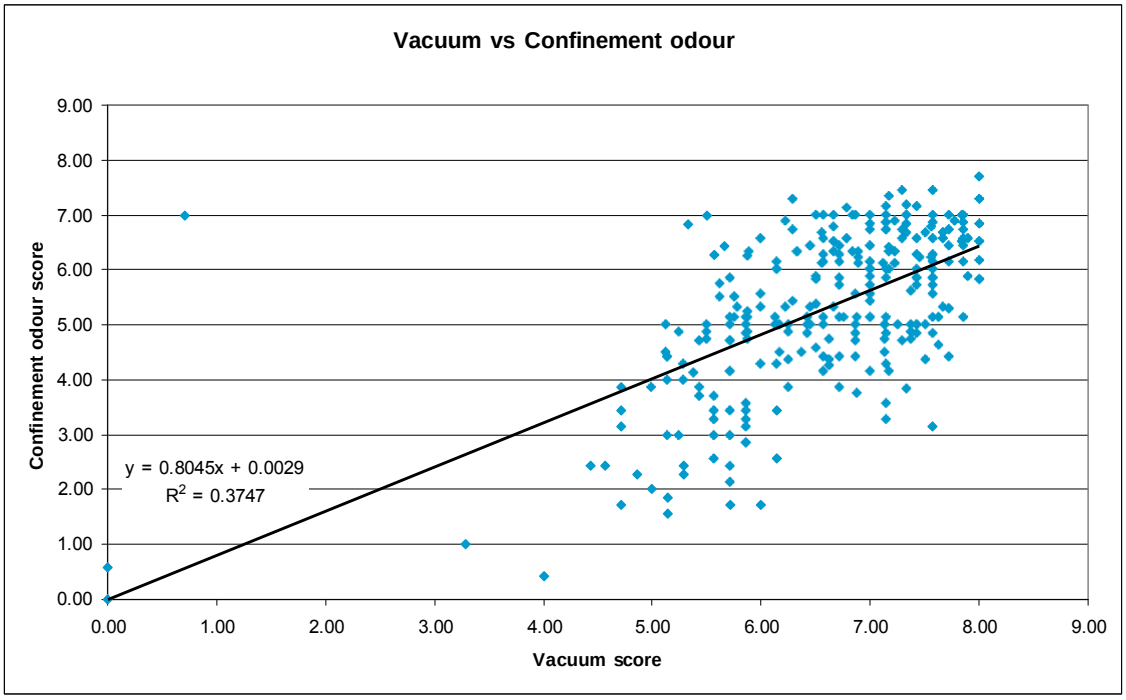


Figure 11: Correlation between vacuum integrity score and confinement odour score: vacuum integrity scale 0 is unacceptable, 8 is excellent; confinement odour scale 0 is extreme off odour, 8 is no off odour

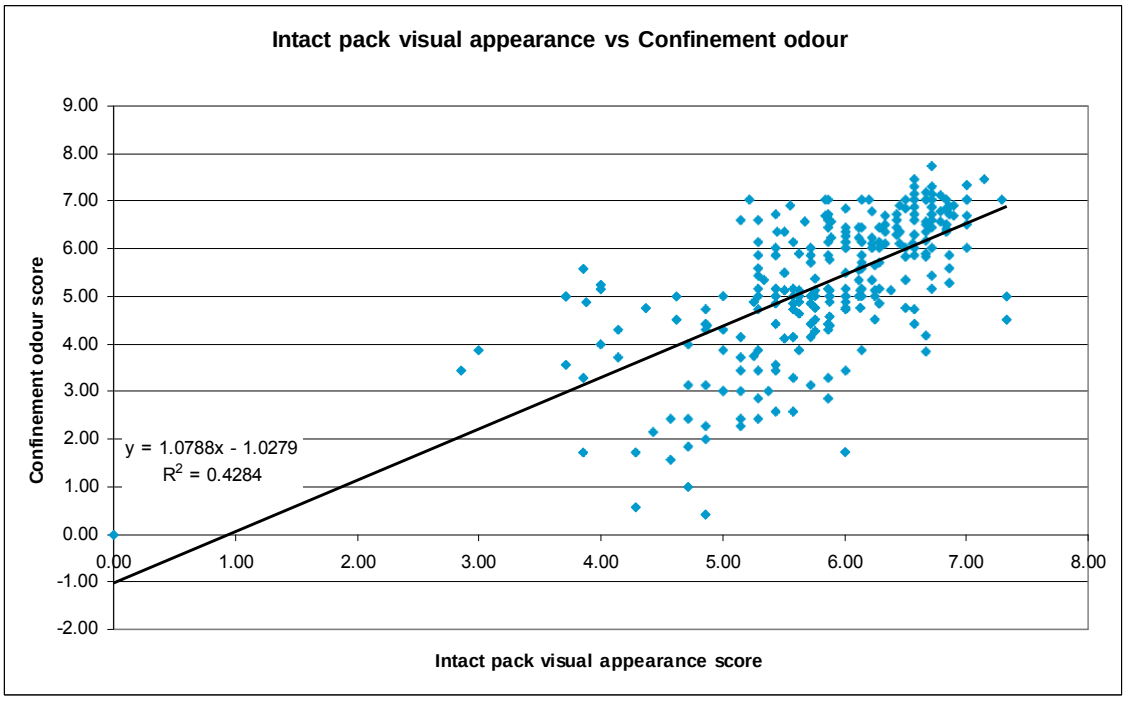


Figure 12: Correlation between intact pack visual appearance score and confinement odour score: visual appearance scale 0 is unacceptable, 8 is excellent; confinement odour scale 0 is extreme off odour, 8 is no off odour

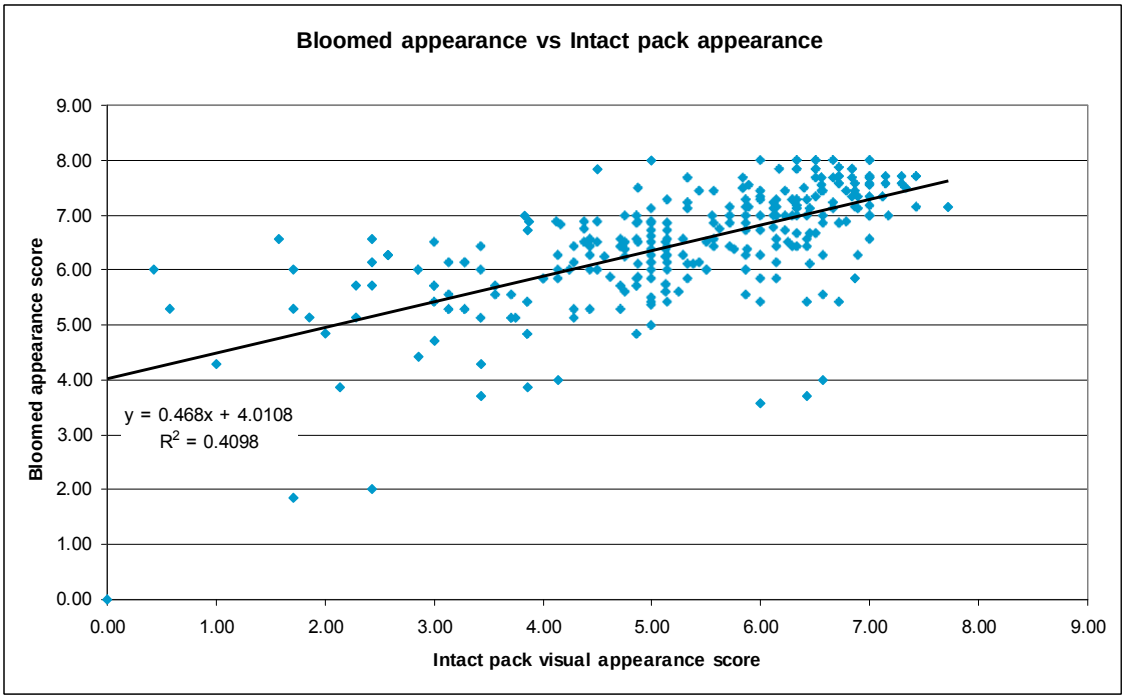


Figure 13: Correlation between bloomed primal visual appearance score and intact pack visual appearance score: both scales 0 is unacceptable, 8 is excellent

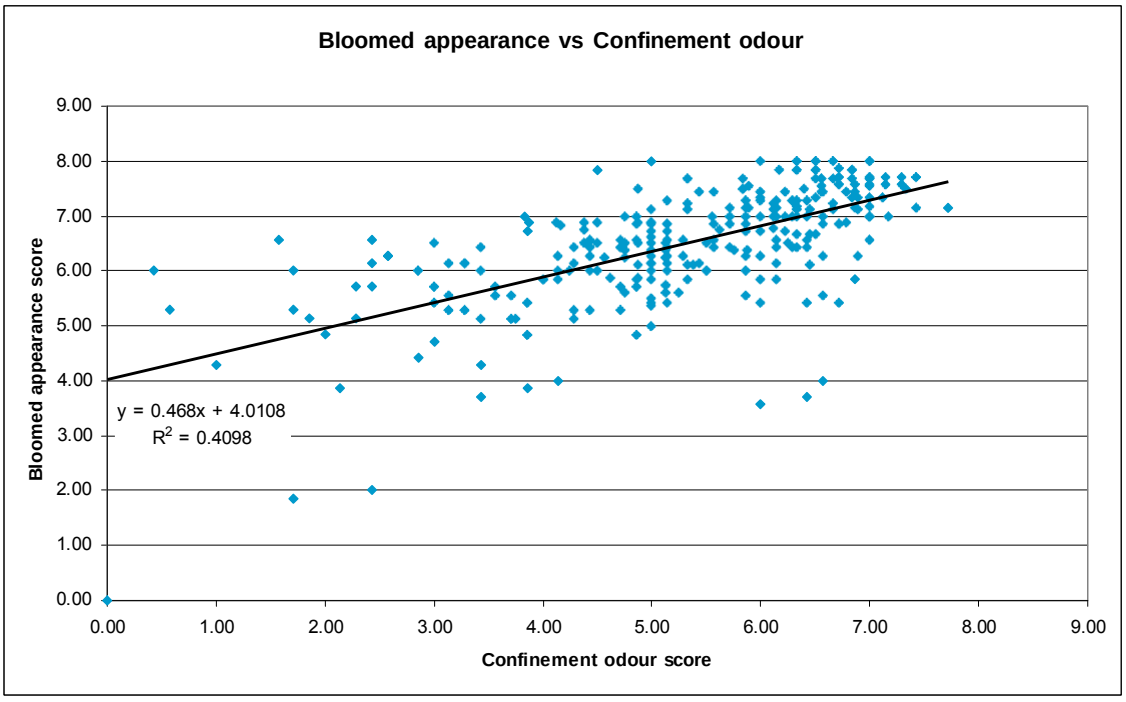


Figure 14: Correlation between bloomed primal visual appearance score and confinement odour score: bloomed primal visual appearance scale 0 is unacceptable, 8 is excellent; confinement odour scale 0 is extreme off odour, 8 is no off odour

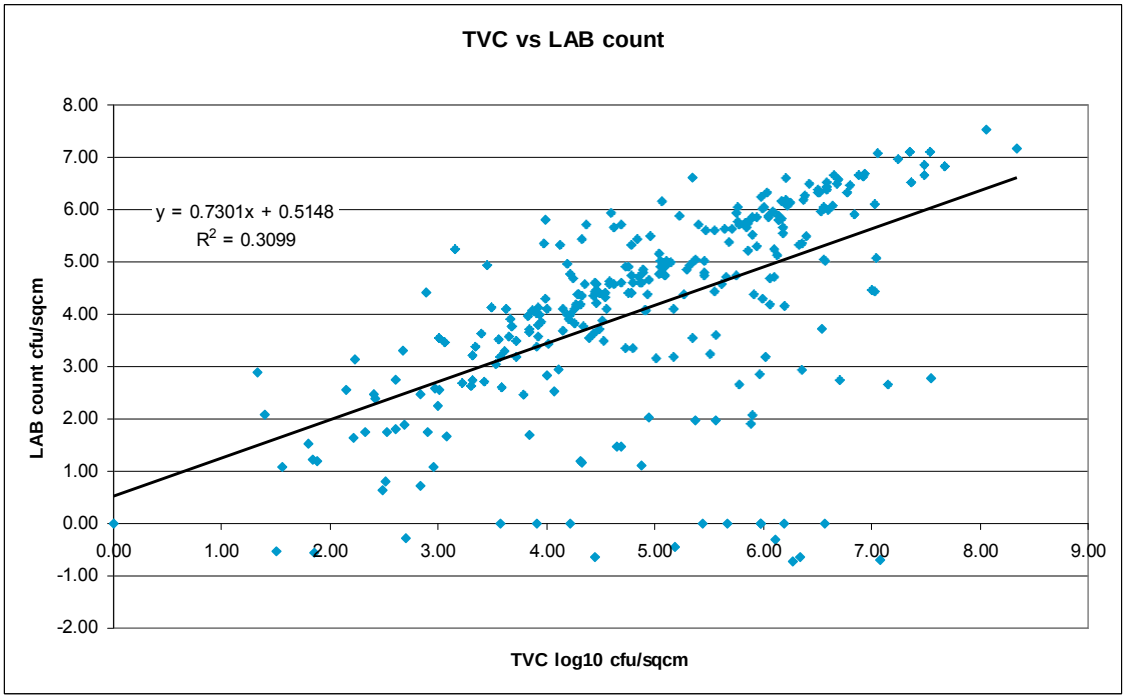


Figure 15: Correlation between TVC and LAB count

6. CONSIDERATIONS FROM A.MFS.0132

The previous study (A.MFS.0132) drew some tentative findings that the current project set out to explore. In the previous project, single primals were sampled at each time point, and only 4 processors were represented. There was a possibility that some of the findings were outliers with regard to the normal situation in Australian export product, as such small sample sizes were used. Thus, the current project aimed to repeat and extend the work, using three of each primal at each sampling point, in order to give a better indication of the mean and distribution of values, and involving an additional 2 processors. Furthermore, as the results of A.MFS.0132 indicated that storage of up to 20 weeks was indeed possible, the current study extended the storage period to 30 weeks, in order to push the boundaries of the validated storage period.

The outcomes from the current project support the findings from A.MFS.0132 (table 13), and indicate that vacuum packed primals from Australian export processors may be confidently stored for 26 weeks or more, under appropriate conditions. More interestingly, when the rates of development of microflora are compared between the two projects, the outcomes are similar. Four processors (B, C, D and E) participated in both projects. Even though the primals for each project were prepared a year apart, the development of LAB in striploins from processors C and D was slower than in striploins from processors B and E, in both projects (figure 16). Similarly in cube rolls, the rate of growth of LAB in product from processor C was lower in both projects than in product from the other processors. In A.MFS.0132, cube rolls from processor B had an intermediate growth rate, but in the current project, the growth rate seemed comparable to that from processors D and E. These trends were similar for TVC (data not shown).

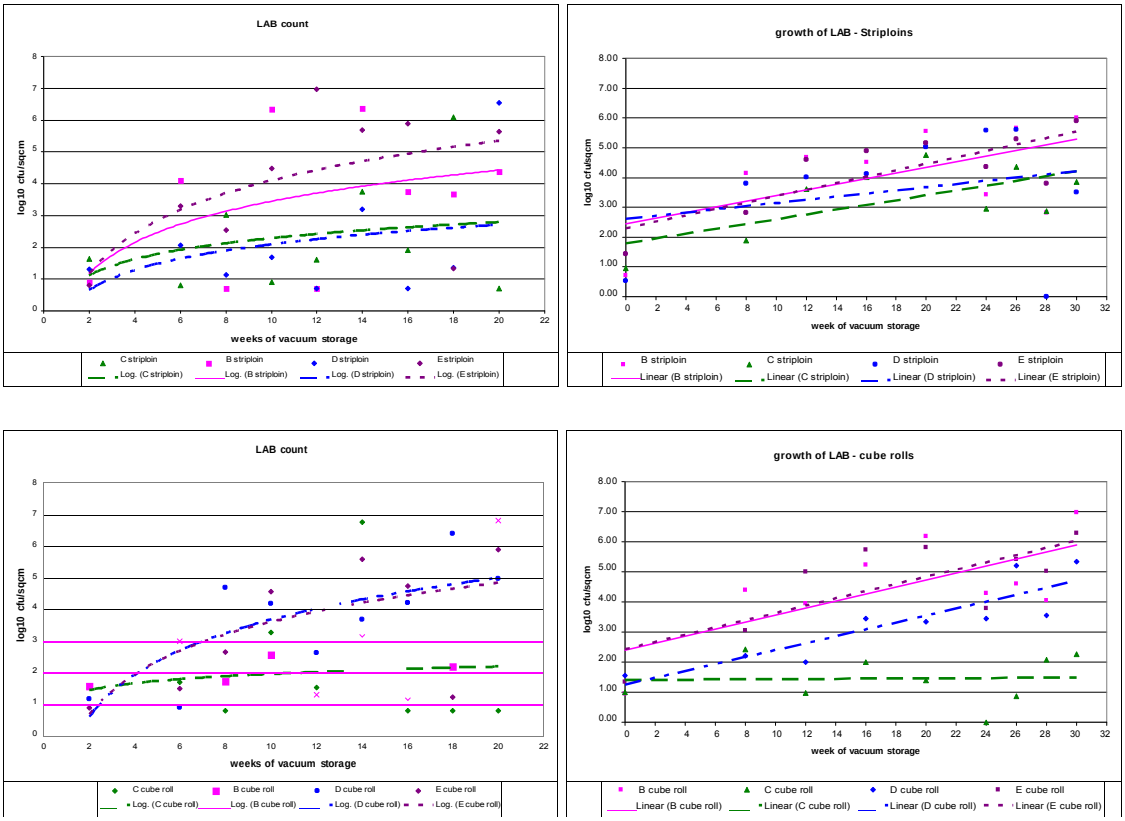


Figure 16: Growth curves of processors B,C,D and E based on mean LAB count from A.MFS.0132 (left), and the current project (right). Striploins at the top, cube rolls below. Trend lines for each processor coloured the same in each chart.

Table 13: Comparison of findings from A.MFS.0132 and the current project

Tentative finding from A.MFS.0132	Related finding from the current project	Finding supported?
TVC and LAB levels are lower than would be expected from published literature, and increases in count are slower than expected	TVC and LAB levels are lower than would be expected from published literature, and increases in count are slower than expected	
Vacuum packed primals from Australian export processors can be confidently stored for up to 20 weeks under appropriate storage conditions	Vacuum packed primals from Australian export processors can be confidently stored for 26 weeks or more under appropriate storage conditions	
Three are differences in the rate of microflora development between processors	There are differences in the rate of microflora development between processors. The individual processors gave similar results in both projects.	

7. CONCLUSION

The data generated by this project support the findings that vacuum packed primals from Australian export processors can be stored confidently for 26 weeks or more, under appropriate conditions. The initial microbial load will be a contributing factor, however, strict temperature control will play a very important role.

Product scored highly for all sensory evaluations up to and beyond 20 weeks of storage. Between 20 and 30 weeks, there was a gradual decline in scores given for visual appearance, and more marked development of confinement odour. Microbiologically, counts of TVC and LAB increased slowly over the storage period, and the expected plateau at 3 weeks of storage was not evident. The mean TVC on day zero ranged from 1.53 to 4.07 $\log_{10}$ cfu/cm^2, from 2.30 to 5.45 $\log_{10}$ cfu/cm^2 at week 8, from 3.24 to 6.32 $\log_{10}$ cfu/cm^2 at week 20, and 3.48 to 7.65 $\log_{10}$ cfu/cm^2 at week 30. In general, LAB counts mirrored TVC, but the range in mean counts detected was more marked. On day zero, LAB counts were between -0.46 and 1.69 $\log_{10}$ cfu/cm^2, at week 8 between 1.88 and 5.08 $\log_{10}$ cfu/cm^2, 1.38 and 6.25 $\log_{10}$ cfu/cm^2 at week 20, and 1.43 and 6.63 $\log_{10}$ cfu/cm^2 at week 30..

More interestingly, there were noticeable differences in the rate of development of the microflora between individual processors, mirroring the differences suggested by project A.MFS.0132. It appeared that the rate of development of LAB in product from processors A, B and E was faster than in product from processors C, D and F, which compares with the findings in A.MFS.0132 that the development of LAB was faster in product from processors B and E than in product from processors C and D.

In terms of taste evaluation in the later stages of storage, in some product, an aged, cheesy or metallic flavour and aftertaste was noticed, but overall the product was considered acceptable, even at week 30.

From this initial data set alone, it would be difficult to predict the point at which the meat has ‘spoiled’, or dropped below the ‘acceptable’ level. This is partially because the evaluations have been carried out on the vacuum packed primals, by a panel of Australian food scientists. In a real supply chain, the consumer, who may be from another country or culture, would be presented with a product that had been prepared into a retail unit, under one of a number of possible packaging options, and storage conditions, which in turn would affect the final outcome of that consumer’s evaluation. Also, there is little relationship between the levels of microbial flora in vacuum packed meat and indicators of spoilage such as off odour or off flavour. This is because the development of these indicators depends on the interaction of the microbial population with the meat substrate itself. Counts of 10^6 would be considered normal in vacuum packed chilled beef, and indicators of spoilage may not develop until much later in storage (Borch et al., 1996, Leisner et al., 1995, Blixt and Borch, 2002).

The data from both this project and A.MFS.0132 have been supplied to the University of Tasmania to assist in the preparation of a predictive model for shelf-life of vacuum packed beef.

However, some interesting queries have arisen out of these two projects:

- Y There seem to be consistent differences between the rate of microflora development on product from different processors. Storage conditions were controlled during the trial, so that all product was stored under the same conditions.
    - What then contributes to the differences in growth rate seen?
    - Are they related to the microbial population present of day zero, and to the microbial populations that develop during storage?
    - Are these populations related to particular persistent microflora in the processing facilities, or to the farms of origin of the livestock processed?
- Y There seems to be little correlation between microbial count and the development of off odours and flavours, when microbial counts remain low.
    - What then contributes to off odours and flavours in long-term aged meat?
- Y During slicing it was observed that well-marbled product maintained its shape and handling texture better than less well-marbled product, which was often described as looking ‘tired’ later in storage.
    - Is there a relationship between degree of marbling and the development of off odours and flavours?
- Y The projects focussed solely on the vacuum packaged product.
    - What effect does long term vacuum storage have no the subsequent life of the product under different packaging and display conditions?

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REFERENCES

BLIXT, Y. & BORCH, E. (2002) Comparison of shelf life of vacuum-packed pork and beef. *Meat Science,* 60**,** 371-378.

BORCH, E., KANT-MUERMANS, M. L. & BLIXT, Y. (1996) Bacterial spoilage of meat and cured meat products. *International Journal of Food Microbiology,* 33**,** 103-120.

ERCOLINI, D., RUSSO, F., TORRIERI, E., MASI, P. & VILLANI, F. (2006) Changes in the Spoilage-Related Microbiota of Beef during Refrigerated Storage under Different Packaging Conditions. *Applied and Environmental Microbiology,* 72**,** 4663-4671.

FONTANA, C., COCCONCELLI, P. S. & VIGNOLO, G. (2006) Direct Molecular Approach to Monitoring Bacterial Colonization on Vacuum-Packaged Beef. *Applied and Environmental Microbiology,* 72**,** 5618-5622.

JONES, R. J. (2004) Observations on the succession dynamics of lactic acid bacteria populations in chill-stored vacuum-packaged beef. *International Journal of Food Microbiology,* 90**,** 273-282.

LEISNER, J. J., GREER, G. G., DILTS, B. D. & STILES, M. E. (1995) Effect of growth of selected lactic acid bacteria on storage life of beef stored under vacuum and in air. *International Journal of Food Microbiology,* 26**,** 231-243.

NISSEN, H. & SORHEIM, O. D. R. (1996) Effects of vacuum, modified atmospheres and storage temperature on the microbial flora of packaged beef. *Food Microbiology,* 13**,** 183-191.

SAKALA, R. M., HAYASHIDANI, H., KATO, Y., HIRATA, T., MAKINO, Y., FUKUSHIMA, A., YAMADA, T., KANEUCHI, C. & OGAWA, M. (2002) Change in the composition of the microflora, on vacuum-packaged beef during chiller storage. *International Journal of Food Microbiology,* 74**,** 87-99.

APPENDIX A – Sensory evaluation form

Date:

Sample number	Attribute				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 Bloom**	**On opening**	

APPENDIX B – Taste panel evaluation forms

CSIRO – Food and Nutritional Sciences
TASTING SCORE SHEET

PANELLIST NAME..... **DATE.....**
SAMPLE ORDER..... **TIME.....**

MEAT AROMA							OTHER AROMA						
SAMPLE							**SAMPLE**						
None							**None**						
Slight							**Slight**						
Moderate							**Moderate**						
Strong							**Strong**						
Very Strong							**Very Strong**						

MEAT FLAVOUR							OTHER FLAVOUR						
SAMPLE							**SAMPLE**						
None							**Very Weak**						
Slight							**Weak**						
Moderate							**Moderate**						
Strong							**Strong**						
Very Strong							**Very Strong**						

CSIRO – Food and Nutritional Sciences
TASTING SCORE SHEET

PANELLIST NAME…… **DATE……**

SAMPLE ORDER…… **TIME……**

OVERALL ACCEPTABILITY						
SAMPLE						
Very Good						
Good						
Moderate						
Poor						
Very Poor						

APPENDIX C – Tables of mean data

Table 14: Vacuum score of striploins and cube rolls

sample	week 8	week 12	week 16	week 20	week 24	week 26	week 28	week 30
A striploin	6.48*	6.50	6.15	5.42	5.71	5.96	5.67	4.86
	(0.30)	(0.58)	(0.34)	(0.14)	(0.00)	(0.51)	(0.22)	(0.14)
B striploin	7.14	6.67	6.19	6.00	6.29	6.04	5.90	5.52
	(0.00)	(0.17)	(0.28)	(0.33)	(0.38)	(0.29)	(0.22)	(0.22)
C striploin	7.10	6.33	6.52	6.50	6.43	6.08	5.67	4.90
	(0.30)	(0.33)	(0.06)	(0.25)	(0.29)	(0.47)	(0.50)	(0.33)
D striploin	7.33	6.06	6.26	6.17	5.76	5.75	5.48	5.05
	(0.08)	(0.63)	(0.53)	(0.44)	(0.36)	(0.13)	(0.46)	(0.36)
E striploin	7.71	8.00	7.85	7.67	7.52	7.42	7.48	5.38
	(0.00)	(0.00)	(0.06)	(0.16)	(0.46)	(0.19)	(0.08)	(0.30)
F striploin	4.76	6.89	6.93	6.38	6.00	5.25	5.52	4.57
	(3.51)	(0.19)	(0.28)	(0.54)	(0.20)	(0.22)	(0.33)	(1.29)
A cube roll	7.81	7.33	7.63	7.57	7.64	7.38	6.81	5.67
	(0.33)	(0.50)	(0.28)	(0.14)	(0.10)	(0.22)	(0.36)	(0.16)
B cube roll	6.95	7.17	7.33	7.19	7.14	6.58	5.05	5.57
	(0.33)	(0.00)	(0.48)	(0.54)	(0.49)	(0.75)	(0.58)	(0.61)
C cube roll	7.33	7.33	6.96	7.38	7.14	7.21	6.00	6.90
	(0.30)	(0.60)	(0.06)	(0.33)	(0.25)	(0.14)	(0.25)	(0.30)
D cube roll	7.67	7.28	7.19	6.38	7.05	7.00	6.81	6.57
	(0.16)	(0.10)	(0.06)	(0.58)	(0.08)	(0.13)	(0.08)	(0.14)
E cube roll	7.05	8.00	7.56	7.57	7.86	7.29	7.43	7.14
	(1.28)	(0.00)	(0.11)	(0.00)	(0.00)	(0.38)	(0.14)	(0.00)
F cube roll	6.86	6.72	6.89	6.81	6.86	6.13	6.52	5.76
	(0.49)	(1.06)	(0.11)	(0.16)	(0.52)	(0.76)	(0.08)	(0.16)

*Mean panel score with standard deviation in parenthesis below
Participating processors designated A - F

Table 15: Intact pack visual appearance score

sample	week 8	week 12	week 16	week 20	week 24	week 26	week 28	week 30
A striploin	6.48*	7.11	5.89	5.63	5.52	5.67	3.19	4.67
	(0.41)	(0.38)	(0.48)	(0.25)	(0.16)	(0.19)	(0.46)	(0.33)
B striploin	6.71	6.61	5.96	5.63	5.71	4.17	5.33	4.86
	(0.25)	(0.19)	(0.50)	(0.13)	(0.43)	(0.40)	(0.16)	(0.38)
C striploin	6.29	6.44	6.26	5.88	6.05	5.75	5.62	4.90
	(0.38)	(0.10)	(0.13)	(0.33)	(0.08)	(0.13)	(0.22)	(0.22)
D striploin	6.57	6.44	6.07	5.67	5.67	5.79	4.33	5.14
	(0.00)	(0.38)	(0.06)	(0.14)	(0.36)	(0.26)	(0.46)	(0.14)
E striploin	6.29	6.50	6.74	6.38	6.57	6.38	5.52	5.14
	(0.14)	(0.17)	(0.13)	(0.08)	(0.38)	(0.13)	(0.22)	(0.14)
F striploin	6.54	6.67	6.33	5.52	5.86	6.13	4.95	4.86
	(0.33)	(0.17)	(0.19)	(0.44)	(0.20)	(0.13)	(0.16)	(0.38)
A cube roll	6.71	5.72	5.59	5.43	4.79	4.63	3.86	3.90
	(0.00)	(0.19)	(0.34)	(0.14)	(0.10)	(0.25)	(0.14)	(0.22)
B cube roll	6.71	6.89	6.81	6.10	6.67	5.96	4.86	4.29
	(0.00)	(0.10)	(0.06)	(0.22)	(0.16)	(0.31)	(0.38)	(0.61)
C cube roll	6.86	6.94	6.19	6.67	6.10	5.58	5.38	5.57
	(0.43)	(0.10)	(0.06)	(0.08)	(0.22)	(0.52)	(0.16)	(0.00)
D cube roll	6.95	6.78	6.15	6.10	6.10	5.96	5.52	5.67
	(0.22)	(0.19)	(0.51)	(0.44)	(0.33)	(0.14)	(0.16)	(0.22)
E cube roll	6.71	6.61	6.07	5.95	5.62	5.58	6.14	5.33
	(0.14)	(0.10)	(0.17)	(0.46)	(0.22)	(0.31)	(0.14)	(0.30)
F cube roll	6.76	6.78	6.63	6.19	5.67	5.71	5.81	5.76
	(0.16)	(0.10)	(0.17)	(0.22)	(0.33)	(0.40)	(0.50)	(0.16)

*Mean panel score with standard deviation in parenthesis below

Table 16: Confinement odour score

sample	week 8	week 12	week 16	week 20	week 24	week 26	week 28	week 30
A striploin	6.33*	4.56	5.22	4.29	4.76	4.13	4.10	2.00
	(0.30)	(0.42)	(0.19)	(1.12)	(0.54)	(0.25)	(0.81)	(0.29)
B striploin	7.00	6.44	6.56	5.21	5.81	4.88	2.81	2.48
	(0.14)	(0.59)	(0.29)	(0.26)	(0.30)	(0.38)	(0.54)	(0.46)
C striploin	6.76	5.67	6.04	5.13	4.67	4.75	4.48	3.52
	(0.41)	(0.58)	(0.67)	(0.25)	(0.70)	(0.38)	(0.22)	(0.44)
D striploin	6.71	6.72	6.41	4.92	3.81	5.46	4.19	3.81
	(0.71)	(0.35)	(0.06)	(0.63)	(1.82)	(0.31)	(0.16)	(0.08)
E striploin	6.71	6.50	6.44	6.14	5.19	4.96	5.52	2.81
	(0.29)	(0.33)	(0.51)	(0.38)	(0.08)	(0.19)	(0.46)	(0.33)
F striploin	6.29	6.61	6.33	6.24	3.29	4.75	4.43	2.10
	(0.71)	(0.54)	(0.38)	(0.30)	(0.20)	(0.25)	(0.29)	(0.97)
A cube roll	7.38	6.67	6.70	5.71	5.07	4.71	5.24	3.52
	(0.30)	(0.33)	(0.26)	(0.52)	(0.91)	(0.31)	(0.30)	(0.22)
B cube roll	6.81	6.24	6.85	5.95	4.81	5.92	2.48	1.79
	(0.16)	(0.21)	(0.23)	(0.16)	(0.44)	(0.31)	(0.93)	(0.10)
C cube roll	6.76	6.56	5.93	6.00	5.57	4.79	5.14	3.86
	(0.22)	(0.10)	(0.34)	(0.57)	(0.65)	(0.26)	(0.29)	(0.49)
D cube roll	7.10	7.17	6.44	5.95	6.14	5.08	5.00	4.57
	(0.30)	(0.17)	(0.40)	(0.16)	(0.25)	(0.07)	(0.14)	(0.25)
E cube roll	6.62	6.06	5.93	5.86	6.48	4.46	4.86	4.24
	(0.30)	(0.38)	(0.51)	(0.29)	(0.30)	(0.64)	(0.14)	(0.64)
F cube roll	6.67	5.89	6.26	6.24	6.57	4.73	5.10	2.90
	(0.73)	(1.78)	(0.34)	(0.22)	(0.14)	(0.15)	(0.08)	(0.36)

*Mean panel score with standard deviation in parenthesis below

Table 17: Post bloom visual appearance score

sample	week 8	week 12	week 16	week 20	week 24	week 26	week 28	week 30
A striploin	7.76*	7.56	6.70	7.04	6.29	6.75	4.95	3.95
	(0.22)	(0.63)	(0.53)	(0.51)	(0.14)	(0.22)	(1.29)	(1.82)
B striploin	6.86	7.72	7.11	6.33	6.43	6.46	6.14	4.76
	(0.94)	(0.25)	(0.00)	(0.29)	(0.00)	(0.72)	(0.14)	(0.93)
C striploin	6.67	7.50	7.04	6.17	6.00	6.50	6.38	5.43
	(0.30)	(0.29)	(0.23)	(0.07)	(0.65)	(0.33)	(0.22)	(0.38)
D striploin	7.00	7.50	6.48	5.79	6.14	6.38	5.81	4.81
	(0.14)	(0.44)	(0.32)	(0.36)	(0.25)	(0.13)	(0.64)	(0.84)
E striploin	7.29	7.78	7.52	6.90	6.38	6.29	6.67	5.62
	(0.29)	(0.10)	(0.17)	(0.36)	(0.44)	(0.63)	(0.59)	(0.16)
F striploin	7.33	7.67	7.07	6.24	4.93	5.83	5.00	3.57
	(0.30)	(0.33)	(0.17)	(0.08)	(0.91)	(0.76)	(0.89)	(1.36)
A cube roll	7.43	8.00	7.59	6.67	6.36	6.88	6.81	5.48
	(0.25)	(0.00)	(0.06)	(0.95)	(0.30)	(0.13)	(0.08)	(0.16)
B cube roll	7.71	7.78	7.33	7.14	6.43	6.54	6.52	5.21
	(0.00)	(0.25)	(0.11)	(0.14)	(0.14)	(0.19)	(0.08)	(0.10)
C cube roll	7.43	7.61	7.24	7.43	7.00	6.46	6.57	6.00
	(0.38)	(0.25)	(0.22)	(0.00)	(0.00)	(0.07)	(0.38)	(0.14)
D cube roll	7.38	7.22	6.57	6.71	5.57	5.67	6.43	6.10
	(0.36)	(0.25)	(0.38)	(0.14)	(0.25)	(0.14)	(0.25)	(0.30)
E cube roll	7.57	7.28	6.52	6.67	5.62	5.88	5.19	5.57
	(0.29)	(0.54)	(0.59)	(0.44)	(0.22)	(0.75)	(0.30)	(0.25)
F cube roll	7.38	7.22	7.29	7.00	6.71	5.92	6.19	6.14
	(0.30)	(0.19)	(0.14)	(0.29)	(0.25)	(0.31)	(0.08)	(0.14)

*Mean panel score with standard deviation in parenthesis below

Table 18: *Brochothrix thermosphacta* count ($log_{10}cfu/cm^2$)

sample	week 0	week 8	week 12	week 16	week 20	week 24	week 26	week 28	week 30
A striploin	not detected	3.61 (1.40)	4.58 (0.61)	4.14 (0.71)	4.30 (1.00)	4.52 (0.83)	4.39 (0.23)	5.73 (0.43)	3.93 (0.62)
B striploin	not detected	not detected	1.78 (0.31)†	2.36 (0.42)	1.84 (0.54)	1.90 (0.16)	2.58 (0.55)	0.84 (0.10)†	2.05 (0.57)
C striploin	not detected	not detected	0.36 (0.06)†	1.59 (0.18)	1.27 (0.39)	0.82 (0.70)†	1.19 (0.22)	0.72#	1.30 (0.13)†
D striploin	not detected	2.66 (0.24)	1.84 (1.11)	1.23 (0.16)†	2.43(0.26)†	1.79 (0.90)	1.29 (0.30)	not detected	0.57 (0.36)
E striploin	not detected	2.45 (0.29)	0.30 (0.00)†	3.45#	not detected	1.43 (0.73)†	not detected	not detected	0.61#
F striploin	not detected	3.62 (0.25)	0.94 (0.19)†	2.10#	0.64 (0.31)	2.56#	1.73 (0.77)	not detected	0.77 (0.64)
A cube roll	not detected	2.95 (0.14)	0.70 (0.05)†	1.63#	not detected	2.79#	1.32 (0.64)	0.69#	2.52 (0.59)
B cube roll	not detected	2.29 (0.10)	not detected	1.64#	0.89 (0.34)†	1.39 (0.35)	0.53 (0.03)†	not detected	1.13 (0.12)
C cube roll	not detected	1.74 (0.55)†	not detected	0.67#	not detected	not detected	not detected	not detected	0.56#
D cube roll	not detected	1.39 (0.55)†	0.65#	0.84#	2.11 (1.06)†	not detected	2.47 (0.46)†	3.60#	0.89 (0.19)
E cube roll	not detected	1.61 (0.16)†	not detected	1.43#	1.29#	not detected	2.05 (0.28)	not detected	0.68#
F cube roll	not detected	1.33 (0.21)	0.82#	1.05 (0.01)†	1.00 (0.53)†	0.65#	1.32 (0.22)	not detected	2.05 (0.46)

*Mean log_{10} cfu/cm², of positive samples, with standard deviation in parenthesis
#Only detected in one primal of three †Only detected in two primals of three Not detected – detection limit 0.25 log_{10} cfu/cm²