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Identifying important points of contamination

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Executive summary

Research has shown that using good hygienic practices on the slaughter line results in lower microbial counts on carcases, but these studies have compared systems using relatively poor practices with systems using combinations of animal washing, sterile gloves, face masks and strict knife sanitation at all stations, and only considered the end-product. Other studies have shown that skinning is a high-impact phase for carcase contamination, and that post-evisceration handling increases the microbial load on carcases. Baseline studies on carcase microbiology in Australian plants have identified that there is a wide range in the microbiological status of carcases produced at different plants. Attempts have been made to identify why this occurs, and understand the factors leading to this variation, through the use of qualitative process evaluation. These have led to some tentative conclusions as to what may constitute a 'good' process, (MLA report PRMS.048B) but no published study explores exactly what happens in terms of microbial movement during the individual dressing operations.

This study aims to examine the amount of microbial transfer from the initial surface to the carcase at individual operations, and how much is picked up by the tools and hands of the operator during the operation.

For the skinning operations, the hide was the most significant potential source of contamination, carrying the greatest microbial load, and the greatest numbers and prevalence of both *E. coli* and *S. aureus*. There was no correlation between hide TVC at either legging or brisket clearing and the carcase TVC at ESAM sampling. TVC on hands and implements were low, and at all stations, particularly at legging and brisket clearing the implement gathered contamination during use. The efficacy of the sanitation procedure was variable. In general the sanitation procedure resulted in a reduction in microbial load on the implement of less than 1 $\log_{10}$, although at brisket clearing, one instance of sanitation resulted in a reduction of 3.0 $\log_{10}$. Increases in microbial load following sanitation were observed on nine occasions during the study.

At legging and bunging, the exposed tissue of the carcase following the operation had mean TVC lower than any other sample taken at that station. At brisket clearing, the mean TVC on the cleared brisket was the same as that on the knife before use. ESAM sampling yielded mean TVC 1 $\log_{10}$ greater than that of the cleared tissue following legging or brisket clearing, and 0.5 $\log_{10}$ greater than the exposed tissue following bunging. Similarly, the ESAM samples were more often contaminated with *E. coli* or *S. aureus* than the exposed tissue samples taken at each dressing station. This suggests that much of the contamination carried by the resultant carcase is picked up later in the process, from other workers or from airborne contamination.

Contents

1 INTRODUCTION

In modern meat production, the major public health hazards are those associated with microbial contamination of the carcase during processing. The hide of cattle is associated with enormous numbers of micro-organisms, which may include food borne pathogens such as *Escherichia coli* (*E. coli*) O157 or other STEC, *Salmonella enterica* or *Campylobacter* spp. During slaughter and dressing, the skin is removed through a series of steps involving manual cutting and handling of the skin, and there are ample opportunities for microorganisms to be transferred from the outer surface of the skin to the carcase surface. Once the skin is removed, the carcase must be eviscerated and trimmed to specification, once more through a series of steps involving cutting and manual handling of the carcase. Measures are taken to minimise leakage of gut content during evisceration, but each handling of the carcase is another opportunity for micro-organisms to be transferred onto the carcase, and for micro-organisms to be transferred from carcase to carcase through cross-contamination.

Research has shown that using good hygienic practices on the slaughter line results in lower microbial counts on carcases, but these studies have compared systems using relatively poor practices with those using combinations of animal washing, sterile gloves, face masks and strict knife sanitation at all stations, and only considered the end-product. Other studies have shown that skinning is a high-impact phase for carcase contamination, and that post-evisceration handling increases the microbial load on carcases. Baseline studies on carcase microbiology in Australian plants have identified that there is a wide range in the microbiological status of carcases produced at different plants. Attempts have been made to identify why this occurs, and understand the factors leading to this variation, through the use of qualitative process evaluation. These have led to some tentative conclusions as to what may constitute a ‘good’ process, (MLA report PRMS.048B) but no published study explores exactly what happens in terms of microbial movement during the individual dressing operations.

2 PROJECT AIM

This study aims to examine the amount of microbial transfer from the initial surface to the carcase at individual operations, and how much is picked up by the tools and hands of the operator during the operation. By understanding the dynamics of cross-contamination at the individual operation, it may be possible to identify the relative importance of particular components of the operation, such as manual handling versus implement, and give

recommendations as to which good practice (the wearing of gloves, or a particular system of implement or hand/arm sanitation) would give the greater impact on carcase hygiene.
This work will provide information on:

- The microbial status of personnel and implements prior to beginning of work
- The level of contamination of the hide or carcase (at the position to be worked upon) prior to the operation
- The microbial status of personnel and used implements, allowing a measurement of the degree of microbial transfer from the carcase or carcase part to the implement
- The microbial status of the carcase surface adjacent to the cutting line, immediately after the task is completed.

From this information it will be possible to assess the effect of an individual operation on the microbial status of the exposed carcase surface and the proportion of contamination transferred to the implements during the operation.

3 METHODS

All samples were collected during the week of 2nd to 6th June 2008, at a processing plant in Queensland. At each of legging, brisket clearing (also known as 'siding in' or 'flanking') and bunging, whirlpak ® sponge samples were taken from:

1. surface before operation begins (300 cm²)
2. operators hands before operation (palms and knuckles of both hands – approximately 340 cm², measured on the operators)
3. tool before operation (both sides of skinning knives - 90 cm² ; or air knives – 78.5 cm², measured on the equipment used)
4. tool immediately after operation (both sides of skinning knives - 90 cm² ; or air knives – 78.5 cm², measured on the equipment used)
5. exposed carcase surface (300 cm²)

Samples were taken in groups of 5 carcase sets. The carcases were tagged and tracked to the scale, and ESAM site samples taken (total area 300 cm²).
Immediately after collection, the sponges were returned to the field laboratory for processing. 90mL of peptone water was added to each sponge (which had been rehydrated prior to sampling

with 10ml saline), and the sponge vigorously massaged by hand for 30 seconds. A decimal dilution series was made from each sample, and plated onto Petrifilm Aerobic®, Petrifilm E. coli® and Petrifilm Staph Express®. The Petrifilm E. coli® and Petrifilm Staph Express® were incubated at 37°C ± 1°C for 24 hours, and the Petrifilm Aerobic ® at 25°C for 72 hours.
Data gathered was entered into an Excel spreadsheet. Aerobic counts (TVC) per square cm and the prevalence of *E. coli* and *Staphylococcus aureus* were calculated for each sample.

4 DESCRIPTION OF OPERATIONS AT EACH SAMPLING SITE

Each dressing station was observed for a period of half an hour by the sampling team before sampling began. This was in order to familiarise the team with the expected normal operations carried out by the operator involved, and to allow the team to optimise the efficiency of sampling. Attempts were made at all stations not to alter the routine carried out by the operators, although the line had to be stopped in between carcases to allow all samples to be taken. However, despite the best intentions of all concerned, there were occasions in which, for example, an implement was not sterilised between carcases, or a sample was missed because the implements were washed too quickly.

4.1 Legging Operation

Samples were taken at skinning of the first hind leg. The operator uses a two-knife system. The first knife is used for the spear cut, to slit the skin over the hock and up to the groin. The knife is then rinsed and placed in the steriliser, the hands are washed and a second knife taken from the steriliser for use clearing the skin from the leg. This knife is then rinsed and returned to the steriliser, the hands washed, and the first knife taken for use on the subsequent carcase. The carcase before (LCB) sample was taken from the hide surface before the first cut was made; the hands before (LHB) and knife before (LKB) samples were taken immediately before the skin clearing part of the operation began; the knife after (LKA) sample taken immediately after clearing, before the knife was sterilised; and the carcase after (LCA) sample taken from the tissue exposed during the clearing operation. Care was taken to ensure that the LCA sample was not contaminated by contact with uncleared skin.

4.2 Brisket Clearing Operation

The carcase before (SCB) sample was taken from the intact skin over the brisket prior to the first cut being made. As for legging, the operator used a knife to perform a spear cut down the belly

and over the brisket to open the skin. This was then placed in the steriliser and the hands washed. The hands were sampled at this point (SHB). An air knife was then used to clear the skin of both sides of the brisket. This was sampled immediately before (SKB) and immediately after use (SKA), before it was sterilised between carcases. The carcase after (SCA) sample was then taken from the exposed brisket tissue.

4.3 Bunging Operation

At bunging, the operator had first to remove a protective plastic sheet from the perineal area. This sheet had been placed there after skinning of the hindquarter, before hide pulling, to protect the area from contamination flicked off the tail. He then dislocated the tail and changed knives before beginning bunging proper. The bunging operation involved cutting around the anus of the carcase, then pulling the rectum out, applying a plastic bag and elastrator ring, and pushing the bagged bung back into the carcase. The knife used for cutting around the anus was placed into a plastic knife pouch (scabbard) while the bagging operation was underway. Once bagging was complete, the knife was returned to the steriliser and the hands washed prior to beginning the subsequent carcase. In order to aid product flow during sampling, the sampler removed the plastic sheet and took the carcase before (BCB) sample from the perineal area, immediately around the anus. The hands (BHB) and knife (BKB) were sampled immediately before the operator began work. During sampling, this operator was not able to change knives between tail dislocation and bunging, and the pressure of the line speed, even with stopping, made it difficult or him to change knives between carcases. The knife was sampled after all operations had been completed on a single carcase (BKA), so after it had been stored in the knife pouch. Finally, the interior of the pelvic inlet was sampled (BCA) where the bunging operation had cut tissue between the anus and pelvis.

4.4 Carcase on Entry to Chill (ESAM sites)

The final sample (ESAM) was taken from the hot carcase, immediately prior to entry to the chill. At this point, the sides had undergone routine trimming. The brisket and flank sites were sampled prior to weighing, the rump sample immediately post weighing, because these positions on the line gave easiest access to the required sites. The left side of each carcase was sampled at the sites specified by the ESAM procedure (Figure 1).

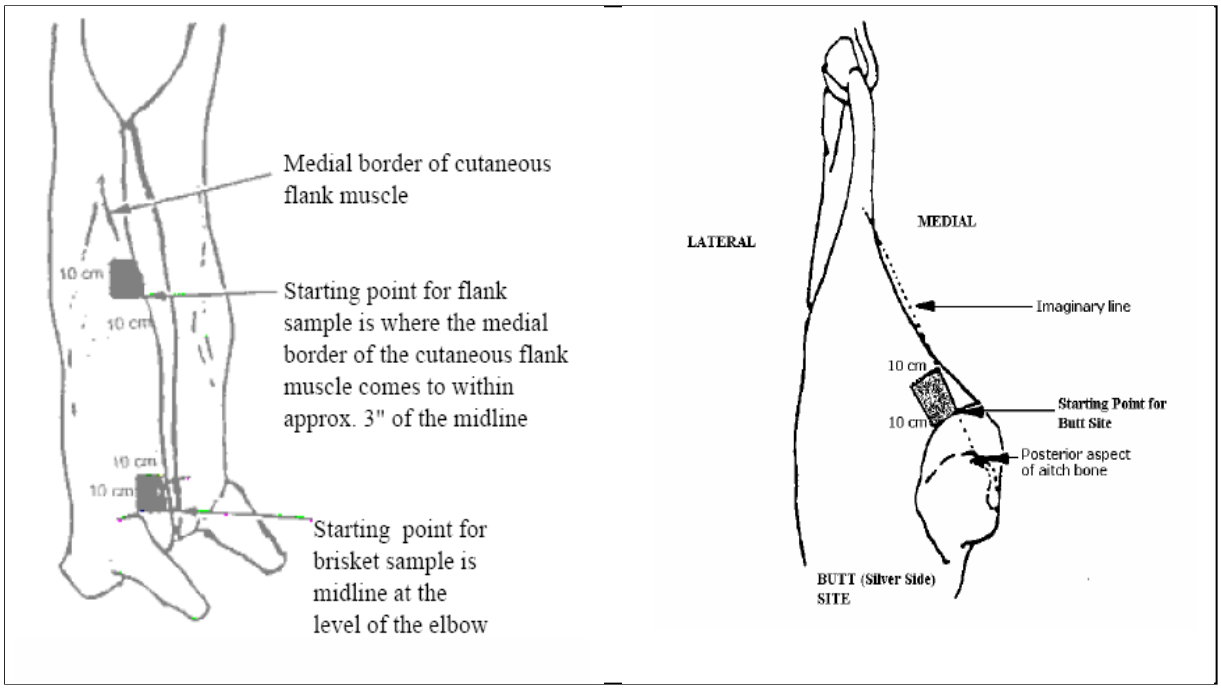

Figure 1: Sampling sites for ESAM

5 RESULTS and ANALYSIS

5.1 ESAM

Final carcase results (ESAM sites) are reported first, as all other results will be compared against these. The mean TVC on hot sides was 1.54 ± 0.69 $\log_{10}$ cfu/cm² (range 0.42 to 3.42) (Figure 2). Four samples yielded *E. coli*, and 17 *S. aureus*. When present, *E. coli* levels were up to 0.67 cfu/cm² (detection limit 0.33), and *S. aureus* up to 1.12 $\log_{10}$ cfu/cm² (mean 0.06 $\log_{10}$ cfu/cm², detection limit 0.33 cfu/cm²).

5.2 TVC

5.2.1 Legging Operation

The mean TVC on the hide prior to opening the first leg was 3.74 ± 0.66 $\log_{10}$ cfu/cm² (range 2.85 to 6.28 $\log_{10}$ cfu/cm²) (Figure 2). The hands prior to beginning the operation were 1.05 ± 0.72 $\log_{10}$ cfu/cm² (range -0.53 to 2.99 $\log_{10}$ cfu/cm²) and the clearing knife prior to use was 1.05 ± 0.52 $\log_{10}$ cfu/cm² (range 0.05 to 2.00 $\log_{10}$ cfu/cm²). After use, the mean TVC on the clearing knife was 1.77 ± 0.80 $\log_{10}$ cfu/cm² (range 0.34 to 2.87 $\log_{10}$ cfu/cm²). The TVC of the cleared tissue after legging was 0.57 ± 0.69 $\log_{10}$ cfu/cm² (range -0.48 to 1.75 $\log_{10}$ cfu/cm²).

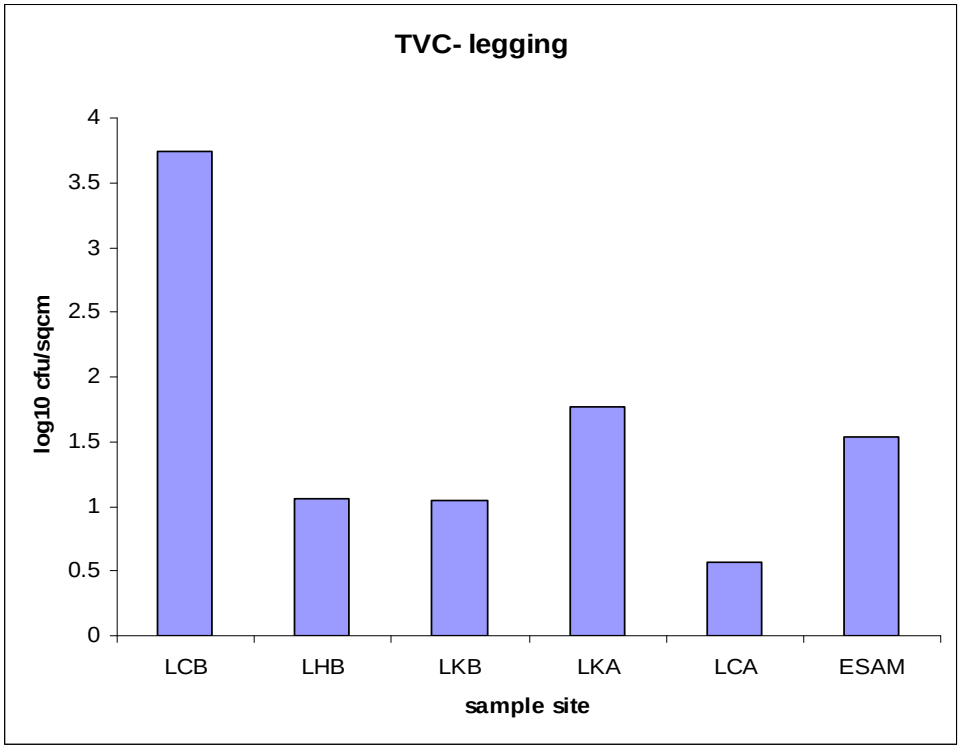

Figure 2: Mean TVC yielded at legging, with ESAM TVC as a comparison

The TVC on hands and on the knife before use over five consecutive carcases were plotted (Figures 3 and 4) in order to investigate whether there was an increase over time. No such trend was evident for either hands or knife.

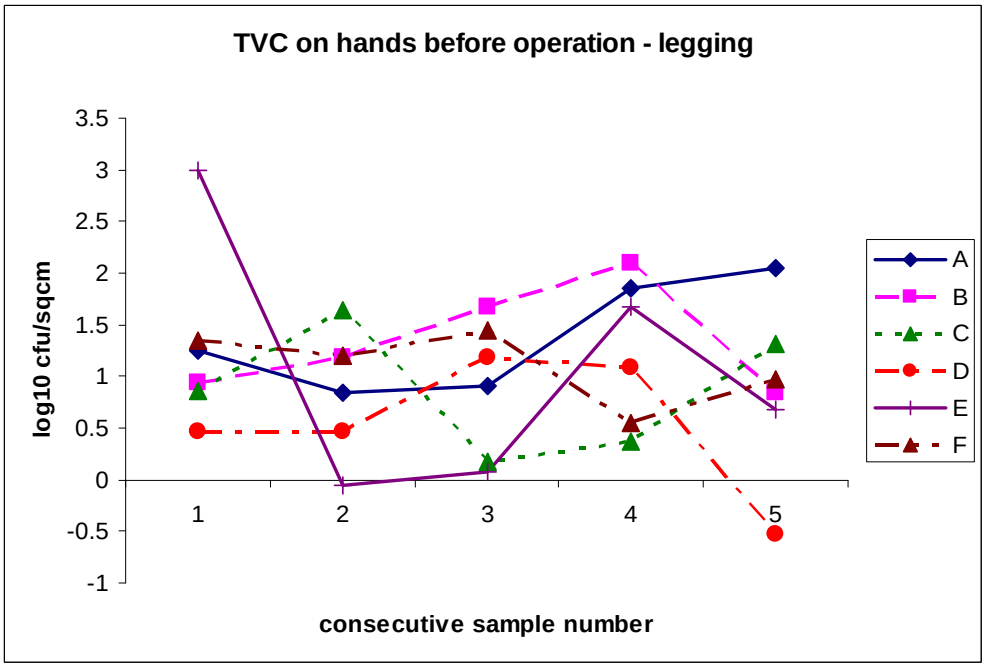

Figure 3: Trend in TVC on hands before operation. Each line (A-F) represents five consecutive carcases

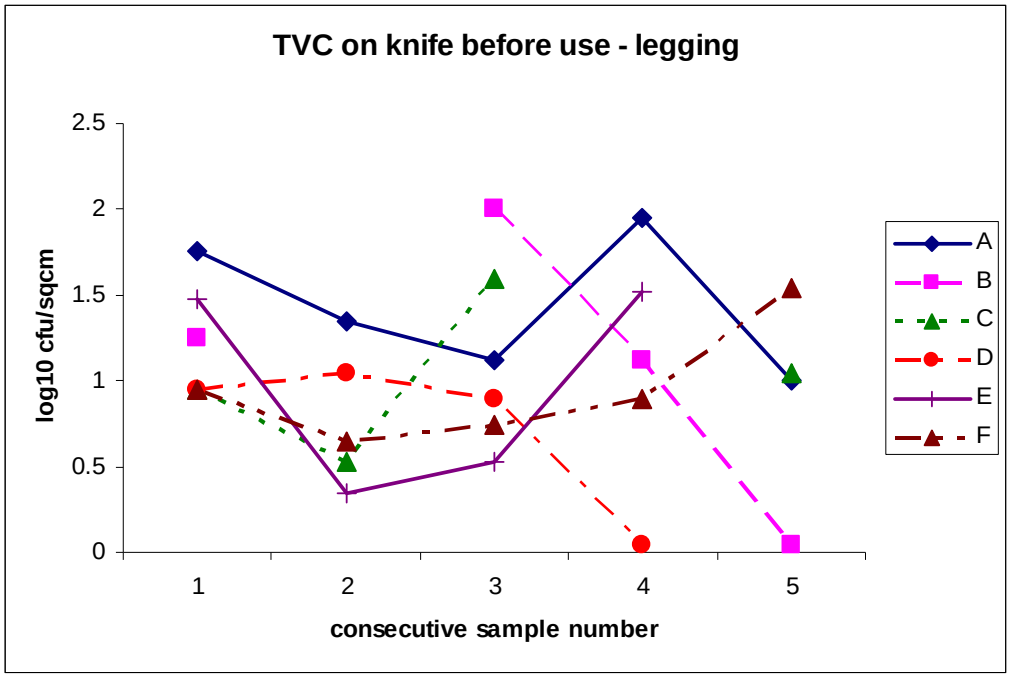

Figure 4: Trend in TVC on knife before use. Each line (A-F) represents five consecutive carcases

Scatter plots were also prepared to examine if there were any relationships between:

- The hide before legging began and the cleared tissue surface (figure 5)
- The hands before legging began and the cleared tissue surface (figure 6)
- The knife before legging began and the cleared tissue surface (figure 7)
- The knife before legging began and the same knife after the operation was completed but before sterilisation (figure 8)
- The knife following legging, before sterilisation and the same knife after sterilisation, before beginning the operation on the subsequent carcase (figure 9)
- The cleared tissue surface following legging and the final hot carcase side at ESAM sampling (figure 10)
- The hide before legging began and the final hot carcase side at ESAM sampling (figure 11)

These relationships were analysed by Pearson's coefficient of correlation. No correlations were identified (correlation coefficients all less than 0.5).

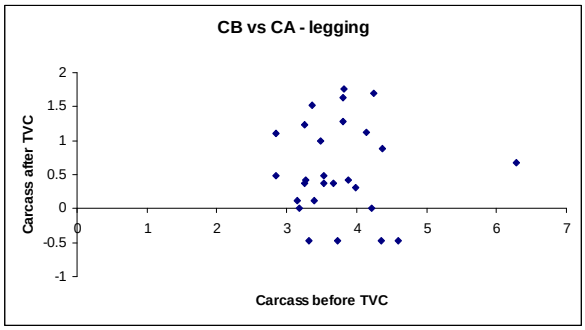

Figure 5: Comparison of TVC on the hide before legging began against TVC of cleared tissue when the legging operation was completed for each carcase

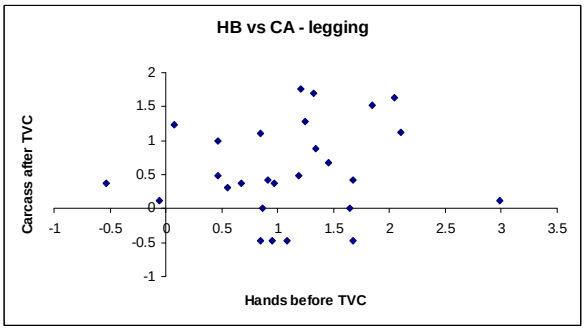

Figure 6: Comparison of TVC on the hands before legging began against TVC of cleared tissue when the legging operation was completed for each carcase

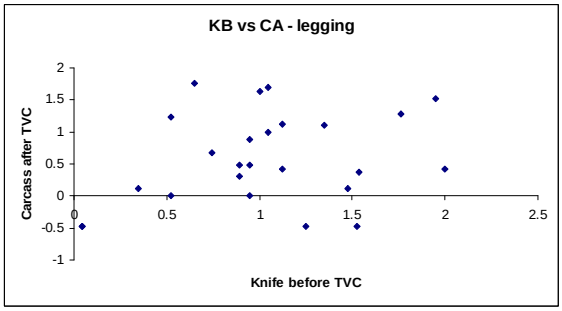

Figure 7: Comparison of TVC on the knife before legging began against TVC of cleared tissue when the legging operation was completed for each carcase

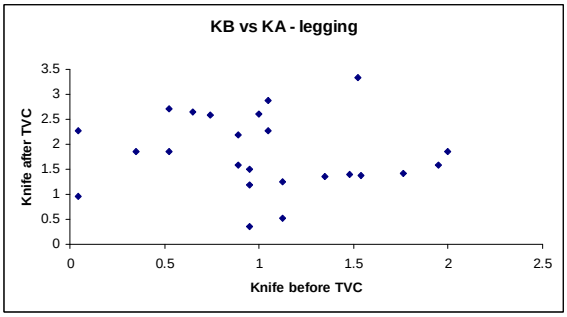

Figure 8: Comparison of TVC on the knife before legging began against TVC of the knife when the legging operation was completed for each carcase

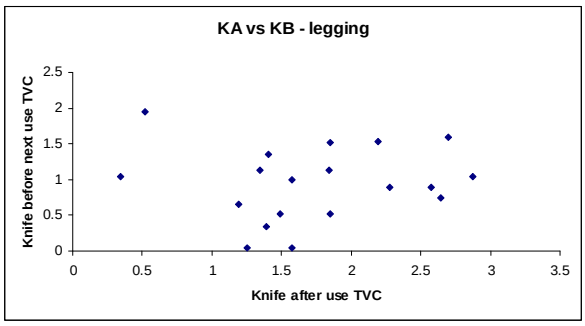

Figure 9: Comparison of TVC on the knife after the legging operation was completed for each carcase, against TVC of that same knife after cleaning and sterilisation, before beginning the subsequent legging operation

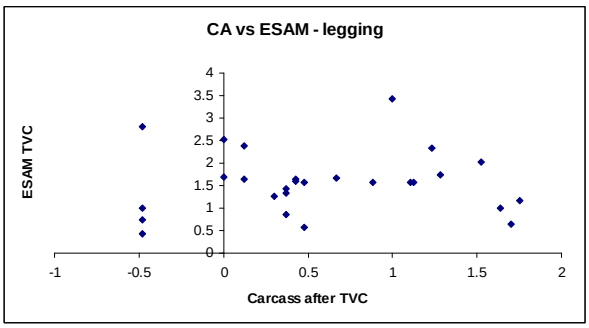

Figure 10: Comparison of TVC on the cleared tissue after legging against TVC of the final hot carcase side at ESAM sampling

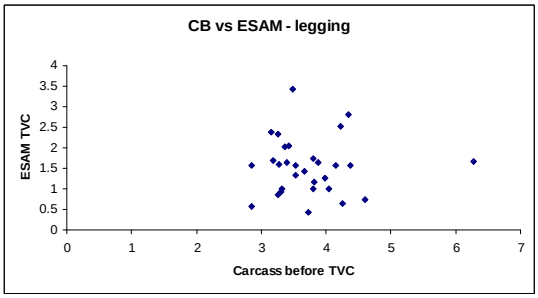

Figure 11: Comparison of TVC on the hide before legging began against TVC of the final hot carcase side at ESAM sampling

5.2.2 Brisket Clearing Operation

At brisket clearing, the mean TVC on the hide prior to opening was 4.76 ± 0.84 log_{10} cfu/cm² (range 3.37 to 7.01 log_{10} cfu/cm²) (Figure 12). The hands prior to beginning the operation had a higher load than at legging, 2.24 ± 0.73 log_{10} cfu/cm² (range 0.93 to 4.01 log_{10} cfu/cm²) and the air knife prior to use was 0.93 ± 0.50 log_{10} cfu/cm² (range 0.41 to 2.38 log_{10} cfu/cm²). After use, the mean TVC on the air knife was 1.65 ± 1.07 log_{10} cfu/cm² (range 0.41 to 3.95 log_{10} cfu/cm²). The TVC of the exposed tissue after brisket clearing was 1.00 ± 0.87 log_{10} cfu/cm² (range -0.48 to 2.90 log_{10} cfu/cm²).

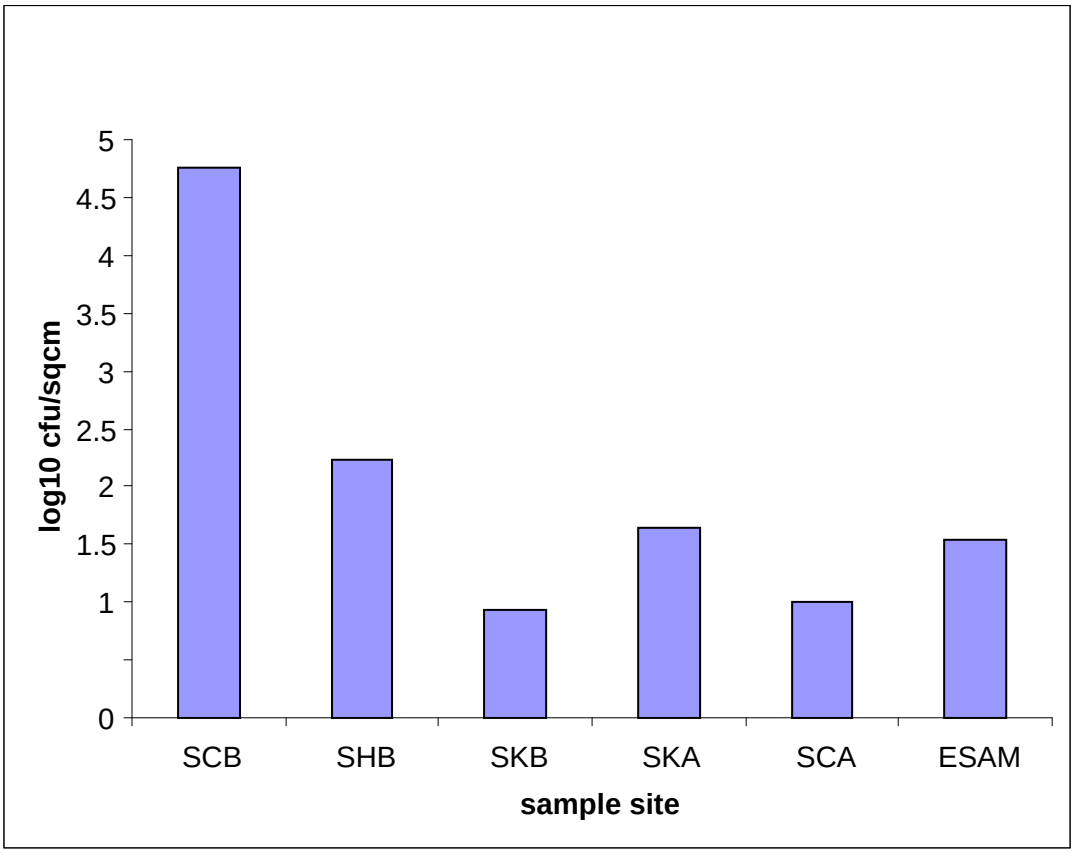

Figure 12: Mean TVC yielded at brisket clearing, with ESAM TVC as a comparison

The TVC on hands and on the knife before use over five consecutive carcases were again plotted (Figures 13 and 14) in order to investigate whether there was an increase over time. No such trend was evident for either hands or knife.

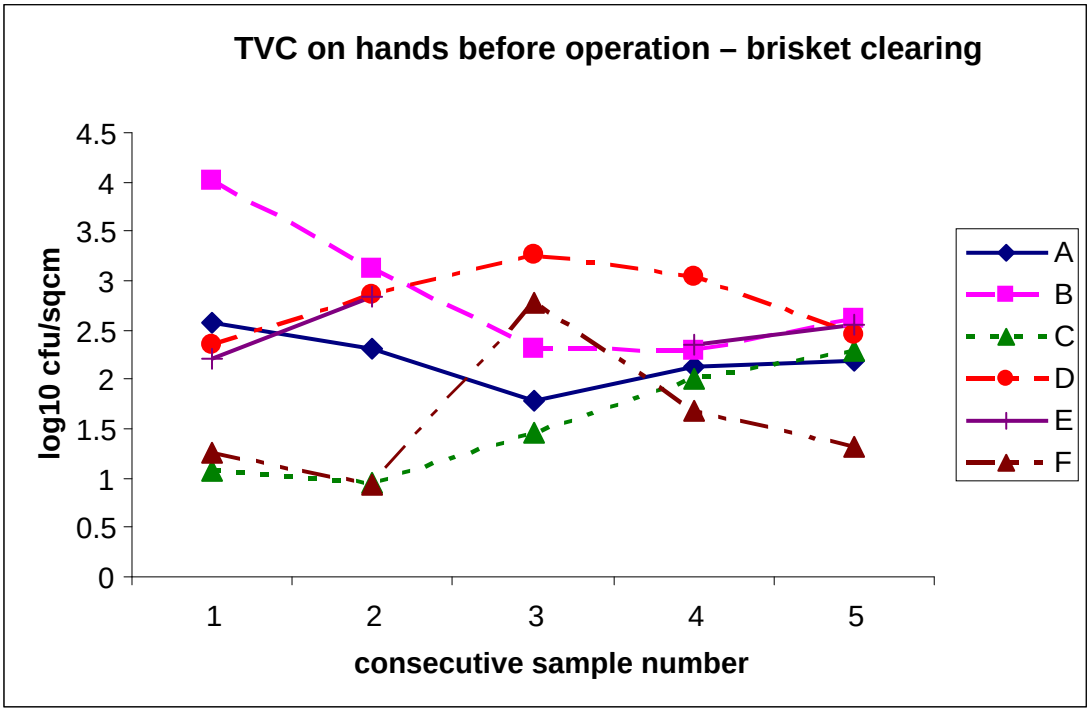

Figure 13: Trend in TVC on hands before operation. Each line (A-F) represents five consecutive carcases

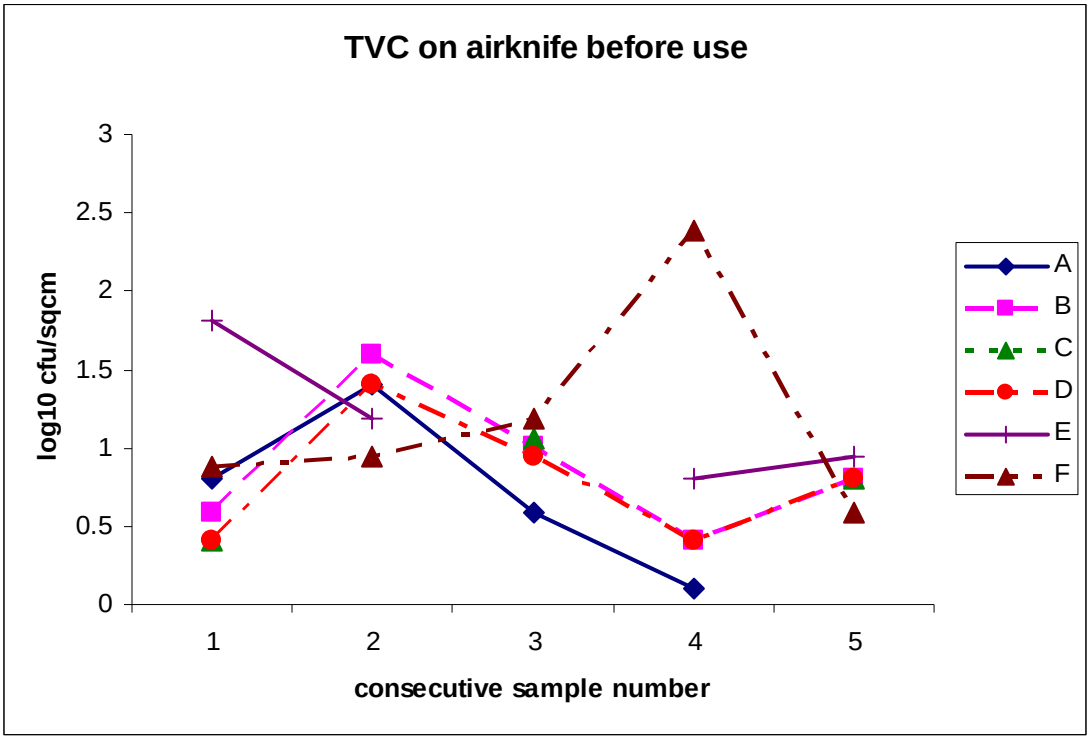

Figure 14: Trend in TVC on air knife before use. Each line (A-F) represents five consecutive carcases

Scatter plots were again prepared to examine if there were any relationships between:

- The hide before brisket clearing began and the cleared tissue surface (figure 15)
- The hands before brisket clearing began and the cleared tissue surface (figure 16)
- The knife before brisket clearing began and the cleared tissue surface (figure 17)
- The knife before brisket clearing began and the same knife after the operation was completed but before sterilisation (figure 18)
- The knife following brisket clearing, before sterilisation and the same knife after sterilisation, before beginning the operation on the subsequent carcase (figure 19)
- The cleared tissue surface following brisket clearing and the final hot carcase side at ESAM sampling (figure 20)
- The hide before brisket clearing began and the final hot carcase side at ESAM sampling (figure 21)

These relationships were analysed by Pearson's coefficient of correlation. No correlations were identified (correlation coefficients all less than 0.5).

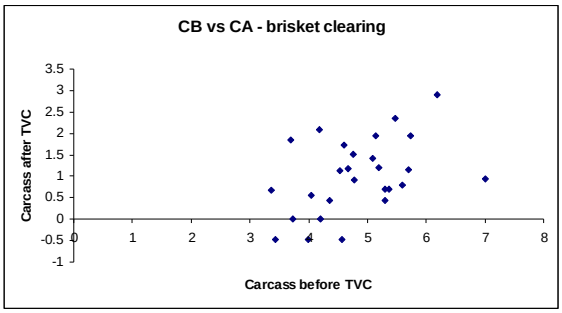

Figure 15: Comparison of TVC on the hide before brisket clearing began against TVC of cleared tissue when the operation was completed for each carcase

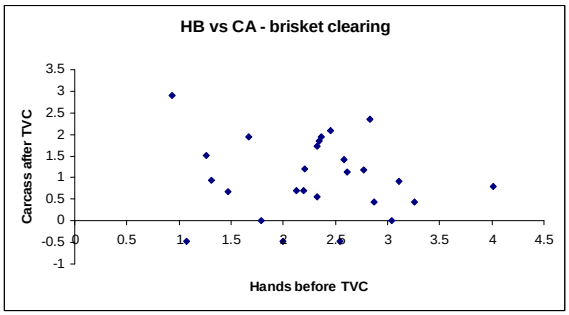

Figure 16: Comparison of TVC on the hands before brisket clearing began against TVC of cleared tissue when the operation was completed for each carcase

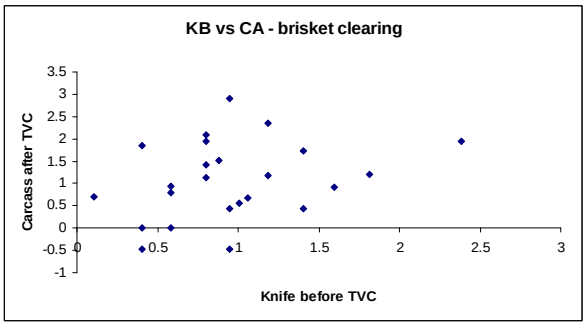

Figure 17: Comparison of TVC on the air knife before brisket clearing began against TVC of cleared tissue when the operation was completed for each carcase

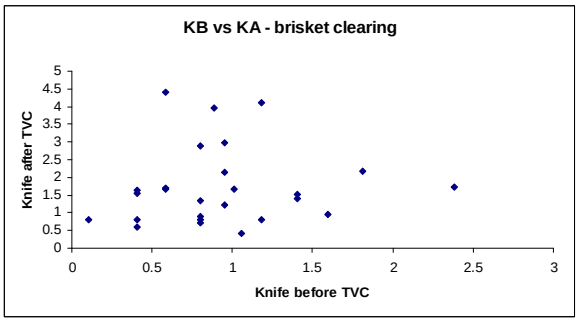

Figure 18: Comparison of TVC on the air knife before brisket clearing began against TVC of the air knife at the end of the operation

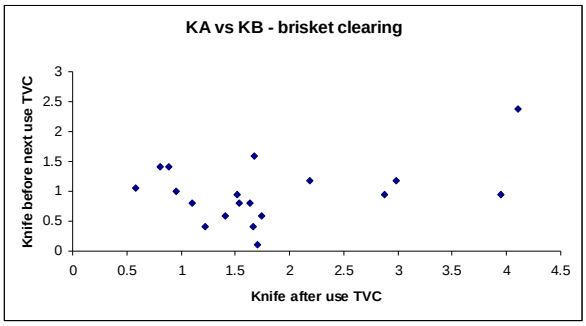

Figure 19: Comparison of TVC on the air knife after the brisket clearing operation against TVC of the air knife following sterilisation, immediately before beginning the operation on the subsequent carcase

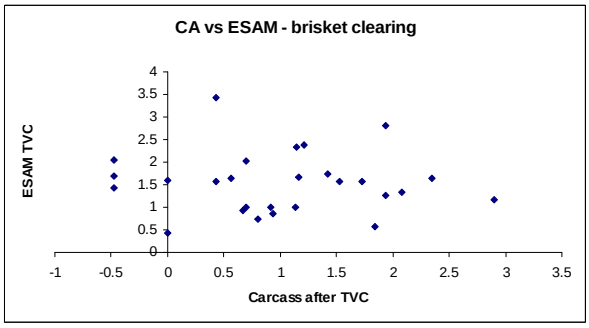

Figure 20: Comparison of TVC on the cleared tissue following brisket clearing against TVC of the final hot carcase side at ESAM sampling

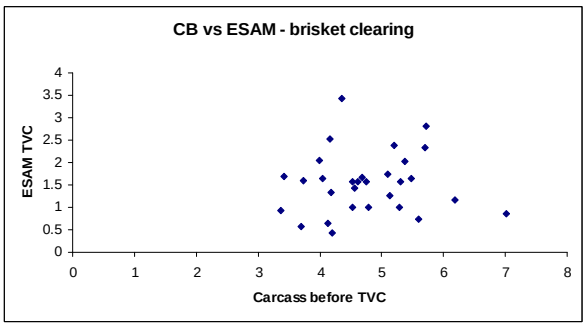

Figure 21: Comparison of TVC on the brisket hide before brisket clearing began against TVC of the final hot carcase side at ESAM sampling

5.3 Bunging Operation

The mean TVC on the perineal tissue prior to beginning bunging was 0.99 ± 0.62 $\log_{10}$ cfu/cm² (range 0.12 to 2.60 $\log_{10}$ cfu/cm²) (Figure 22). The hands prior to beginning the operation were 0.83 ± 0.37 $\log_{10}$ cfu/cm² (range -0.23 to 1.61 $\log_{10}$ cfu/cm²) and the knife prior to use was 0.92 ± 0.44 $\log_{10}$ cfu/cm² (range 0.35 to 1.87 $\log_{10}$ cfu/cm²). After use, the mean TVC on the knife was 1.06 ± 0.61 $\log_{10}$ cfu/cm² (range 0.05 to 2.00 $\log_{10}$ cfu/cm²), while the TVC of the exposed tissue in the pelvic inlet was 0.58 ± 0.45 $\log_{10}$ cfu/cm² (range -0.48 to 1.61 $\log_{10}$ cfu/cm²).

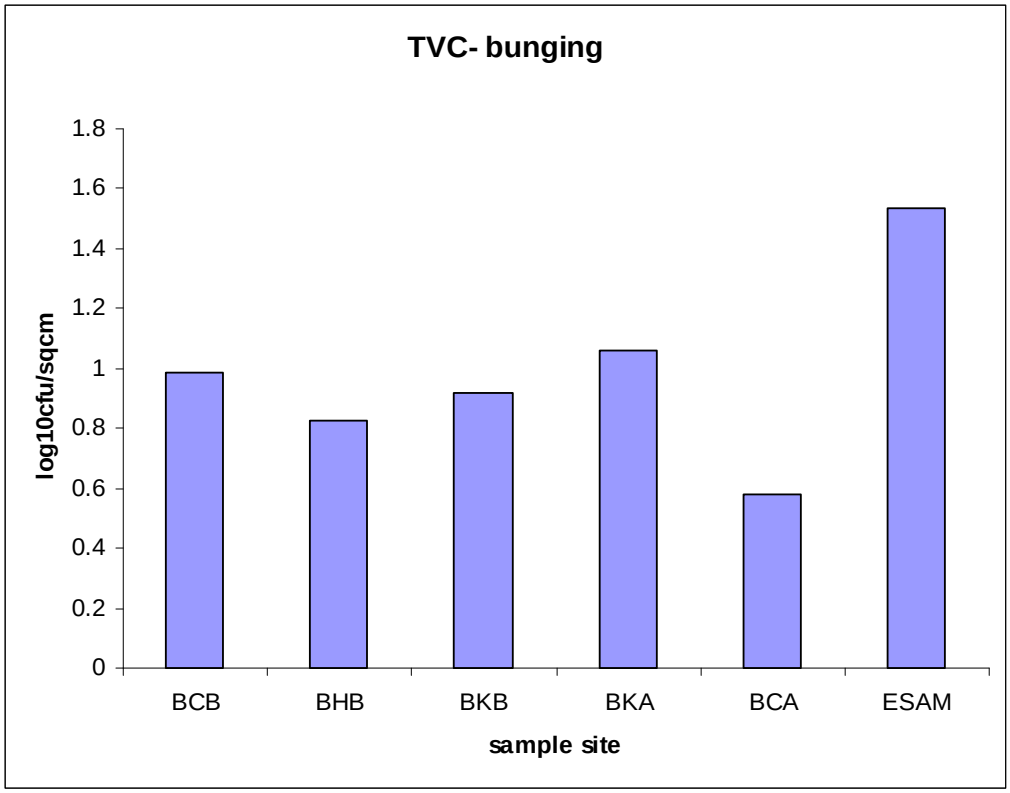

Figure 22: Mean TVC yielded at bunging, with ESAM TVC as a comparison

The TVC on hands and on the knife before use over five consecutive carcases were again plotted (Figures 23 and 24) in order to investigate whether there was an increase over time. Although there seemed to be an overall increase in TVC on the hands during sample set B, this trend was not consistent, and no such trend was evident for the knife.

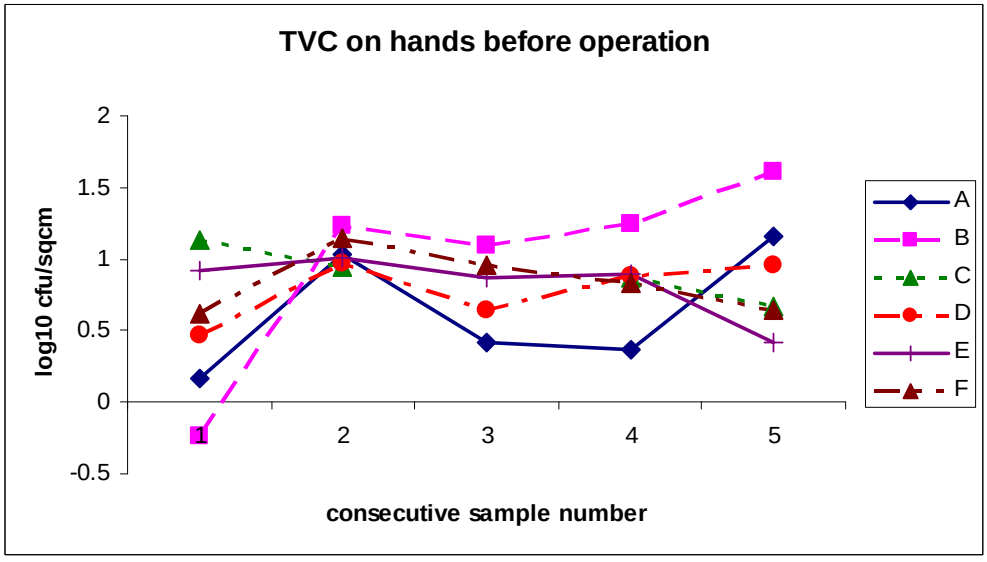

Figure 23: Trend in TVC on hands before operation. Each line (A-F) represents five consecutive carcases

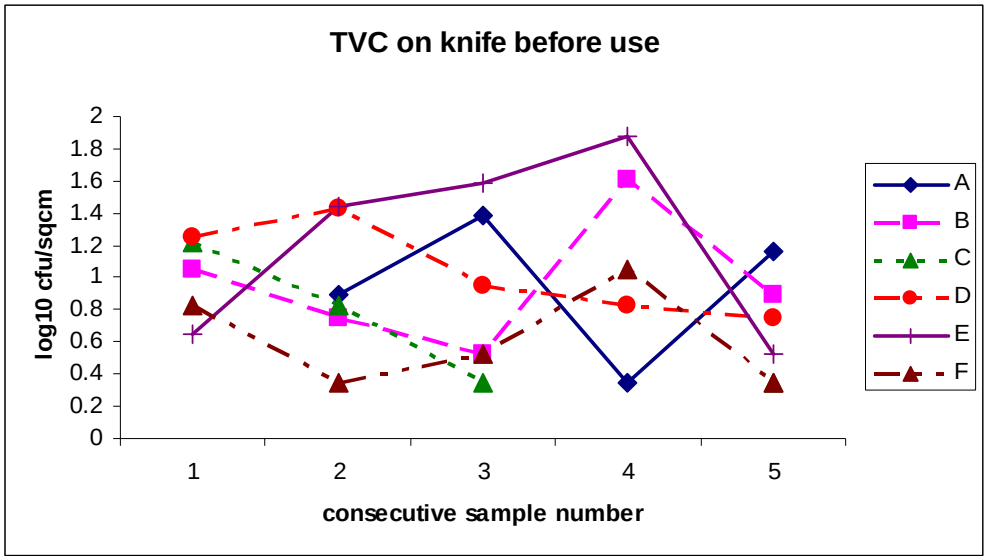

Figure 24: Trend in TVC on knife before use. Each line (A-F) represents five consecutive carcases

Scatter plots were again prepared to examine if there were any relationships between:

- The perineal tissue surface before bunging began and the exposed tissue in the pelvic inlet (figure 25)
- The hands before bunging began and the exposed tissue in the pelvic inlet (figure 26)
- The knife before bunging began and the exposed tissue in the pelvic inlet (figure 27)
- The knife before bunging began and the same knife after the operation was completed but before sterilisation (figure 28)
- The knife following bunging, before sterilisation and the same knife after sterilisation, before beginning the operation on the subsequent carcase (figure 29)
- The exposed tissue in the pelvic inlet following bunging and the final hot carcase side at ESAM sampling (figure 30)
- The perineal tissue surface before bunging began and the final hot carcase side at ESAM sampling (figure 31)

These relationships were analysed by Pearson's coefficient of correlation. No correlations were identified (correlation coefficients all less than 0.5).

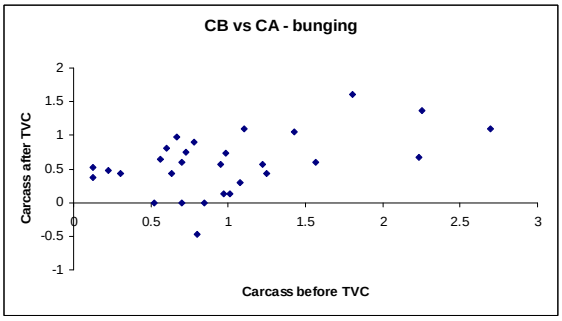

Figure 25: Comparison of TVC on the perineal area before bunging began against TVC of the exposed tissue of the pelvic inlet when the operation was completed for each carcase

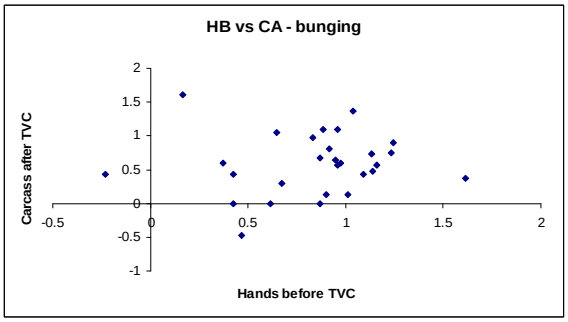

Figure 26: Comparison of hands before bunging began against TVC of the exposed tissue of the pelvic inlet when the operation was completed for each carcase

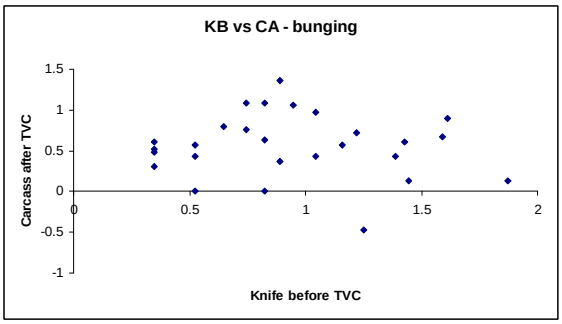

Figure 27: Comparison of TVC on the knife before bunging began against TVC of the exposed tissue of the pelvic inlet when the operation was completed for each carcase

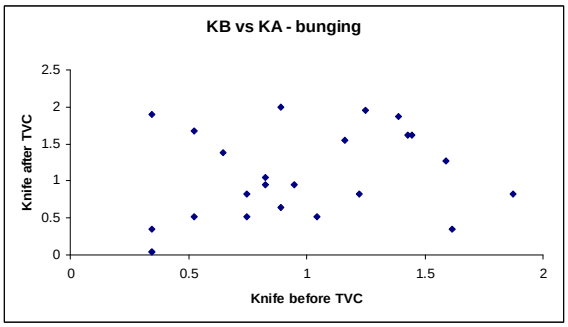

Figure 28: Comparison of TVC on the knife before bunging began against TVC of the knife when the operation was completed for each carcase

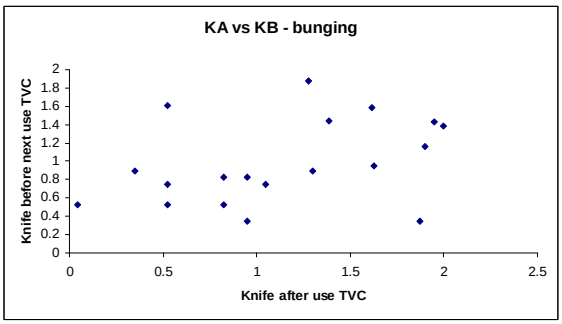

Figure 29: Comparison of TVC on the knife after bunging was completed against TVC of knife following sterilisation, immediately before beginning the bunging operation on the subsequent carcase

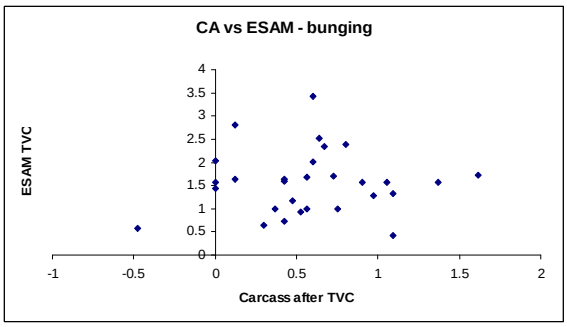

Figure 30: Comparison of TVC on the exposed tissue of the pelvic inlet when the bunging operation was completed against TVC of the hot carcase side at ESAM sampling

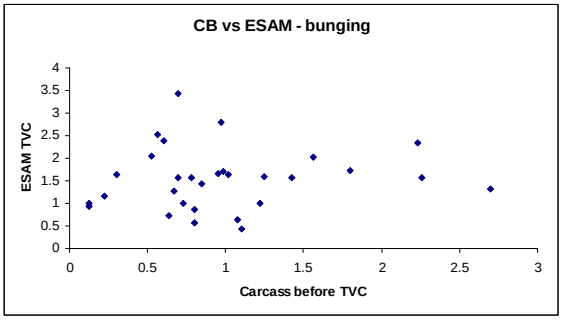

Figure 31: Comparison of TVC on the perineal are before bunging began against TVC of the hot carcase side at ESAM sampling

5.4 E. coli

At the legging station, *E. coli* was found on the hide of nine carcases (figure 33), at levels of up to 2.52 $\log_{10}$ cfu/cm². Two hand samples at legging yielded *E. coli* (-0.53 and -0.23 $\log_{10}$ cfu/cm²), and four samples taken from the clearing knife after use (mean count 0.28 $\log_{10}$ cfu/cm² when present, range 0.05 to 1 $\log_{10}$ cfu/cm²). No *E. coli* were detected on the knife prior to use or from the cleared tissue after legging was completed.

At brisket clearing, *E. coli* was again detected on the hides of nine carcases, counts of up to 2.43 $\log_{10}$ cfu/cm²; and from four hand samples, counts of up to 0.17 $\log_{10}$ cfu/cm². No *E. coli* were detected on any knife sample or from cleared tissue at brisket clearing.

E. coli were detected on the perineal tissue of eight carcases immediately prior to bunging, at levels up to 1.32 $\log_{10}$ cfu/cm², from four hand samples at levels of up to 2.43 $\log_{10}$ cfu/cm², and from one knife sample (0.83 $\log_{10}$ cfu/cm²) prior to beginning bunging. No *E. coli* were detected on the bunging knife after the operation was completed, while two samples taken from the exposed tissue at the pelvic inlet yielded *E. coli* (-0.18 and -0.48 $\log_{10}$ cfu/cm²).

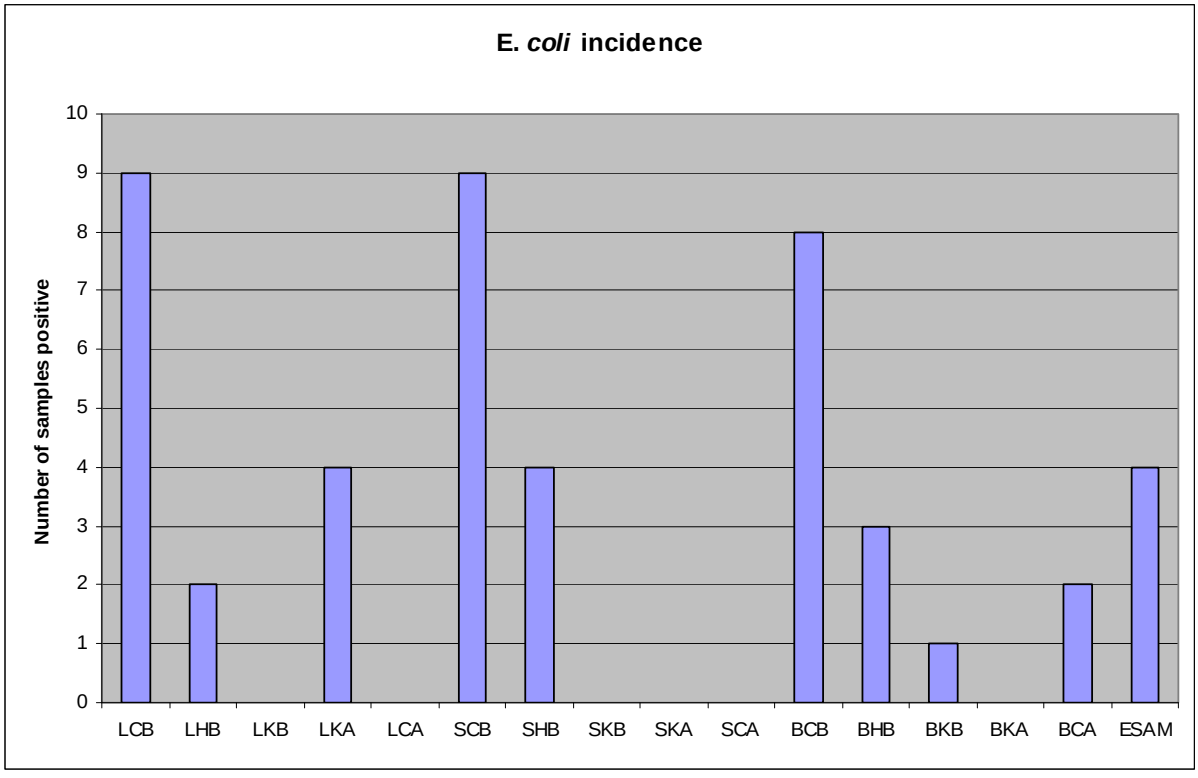

Figure 32: Number of samples positive for *E. coli* at each sample site (n=30)

5.5 Staphylococcus aureus

High numbers of *S. aureus* were present on the hides of carcases. At legging, 28 hides yielded *S. aureus* (figure 34), at levels of up to 4.23 $\log_{10}$ cfu/cm² (mean 2.06 $\log_{10}$ cfu/cm²), while at brisket clearing, 23 hides were positive, at levels of up to 4.36 $\log_{10}$ cfu/cm² (mean 2.47 $\log_{10}$ cfu/cm²). *S. aureus* was also found on 8 hand samples at legging (up to 1.51 $\log_{10}$ cfu/cm², mean -0.06 $\log_{10}$ cfu/cm²) and 16 hand samples at brisket clearing (up to 2.37 $\log_{10}$ cfu/cm², mean 0.44 $\log_{10}$ cfu/cm²). Three samples from the knife before legging were positive (all 0.05 $\log_{10}$ cfu/cm²), and 11 from the knife after (mean 0.36 $\log_{10}$ cfu/cm², maximum 1.09 $\log_{10}$ cfu/cm²), while only 2 samples from the cleared tissue post legging yielded *S. aureus* (0.30 and 0.00 $\log_{10}$ cfu/cm²).

At brisket clearing, two samples from the airknife before use (0.11 and 0.41 $\log_{10}$ cfu/cm²), five after use (mean 0.43, maximum 0.707 $\log_{10}$ cfu/cm²) and three samples from the cleared brisket (one at 0.67 and two at -0.47 $\log_{10}$ cfu/cm²) were positive.

S. aureus was detected on the perineal tissue of seven carcases at bunging (mean -0.37 $\log_{10}$ cfu/cm², maximum 0.301 $\log_{10}$ cfu/cm²), on a single hand sample (-0.23 $\log_{10}$ cfu/cm²), on two each of knife before (both 0.05 $\log_{10}$ cfu/cm²) and knife after (0.05 and 1.05 $\log_{10}$ cfu/cm²) samples, and on four samples from the pelvic inlet after bunging (mean -0.16 $\log_{10}$ cfu/cm², maximum 0.00 $\log_{10}$ cfu/cm²).

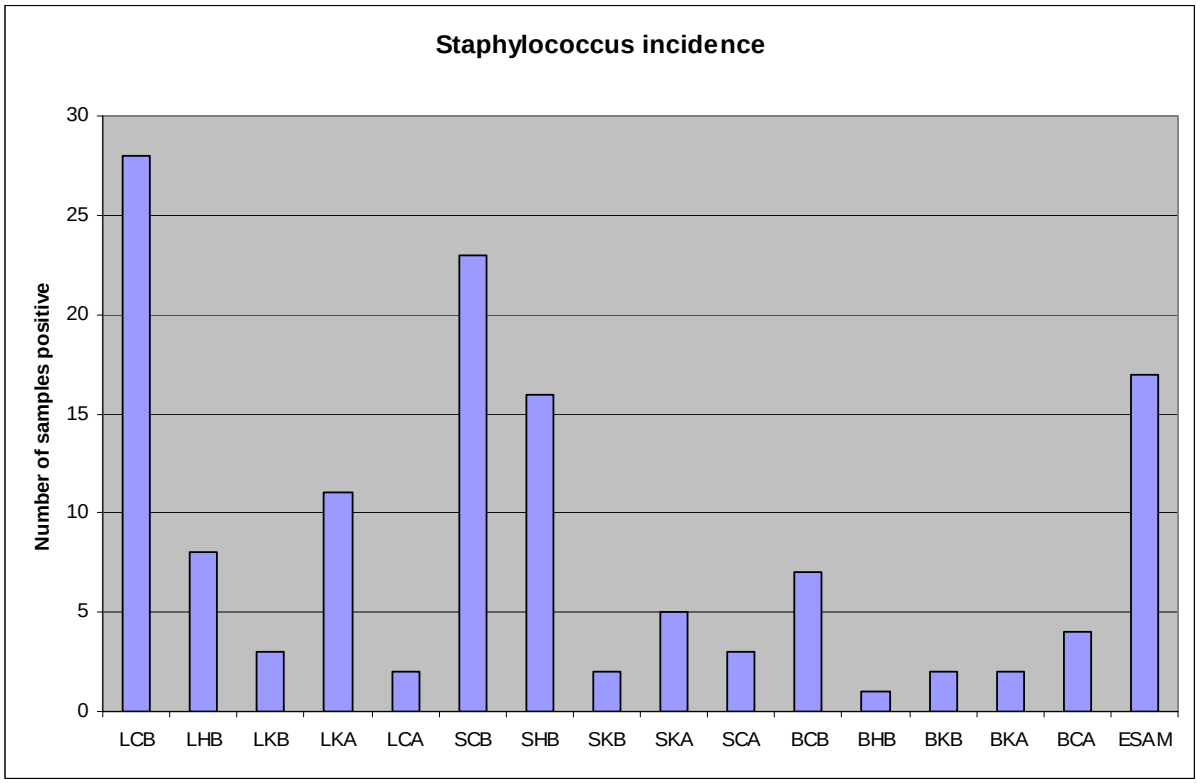

Figure 33: number of samples positive for *S. aureus* at each sample site (n=30)

5.6 Efficacy of implement sterilisation

The mean reduction in TVC achieved by implement sanitisation was 0.59 log_{10}overall. At legging the maximum reduction was 1.90 log_{10}, the minimum a 1.43 log_{10} increase, and the mean reduction 0.79 log_{10}. At brisket clearing, the maximum reduction was 3.00 log_{10}, the minimum a 0.52 log_{10} increase, and the mean reduction 0.84 log_{10}. At bunging, the maximum reduction achieved was 1.52 log_{10}, the minimum a 1.09 log_{10} increase and the mean reduction 0.15 log_{10}. Increases in microbial load were seen on 5 of 24 occasions at legging, 4 of 24 occasions at brisket clearing and one of 14 occasions at bunging.

6 DISCUSSION

For the skinning operations, as expected, the hide was the most significant potential source of contamination, carrying the greatest microbial load, and the greatest numbers and prevalence of both *E. coli* and *S. aureus*. This supports previous work on beef dressing practices (Hudson et al., 1998, Bell, 1997, Elder et al., 2000, Stolle, 1981, Roberts et al., 1984). Newton *et al.* (1978) suggested that final carcase counts are an almost constant fraction of those on hides (0.3%), which was broadly agreed by Vivas-Alegre and Buncic in 2004, although those authors found that this fraction differed between abattoirs (Vivas Alegre and Buncic, 2004). However, the present study found no correlation between hide TVC at either legging or brisket clearing and the carcase TVC at ESAM sampling.

Previous authors have suggested that the hands of workers can be a source of contamination for carcases (Pether and Gilbert, 1971), and improving dressing hygiene through a combination of strict sanitation of tools, wearing of gloves and carcase decontamination has been recommended for reducing the microbial load of carcases (Graves-Delmore et al., 1998, Gill and Jones, 2002, Chandran et al., 1986, Bacon et al., 2000). The workers involved in the present study all wore rubber gloves, and used a two-knife system for sanitising their implements, with sterilisers running at 82°C. As such, TVC on hands and implements were low, although at brisket clearing, the mean TVC on hands was 2.24 log_{10} cfu/cm², compared with 1.65 log_{10} cfu/cm² on the airknife. At all stations, particularly at legging and brisket clearing the implement gathered contamination during use, as to be expected. However, the efficacy of the sanitation procedure was variable. In general the sanitation procedure resulted in a reduction in microbial load on the implement of less than 1 log_{10}, although at brisket clearing, one instance of sanitation resulted in a reduction of 3.0 log_{10}. Increases in microbial load following sanitation were observed on nine occasions during the study.

At legging and bunging, the exposed tissue of the carcase following the operation had mean TVC lower than any other sample taken at that station. At brisket clearing, the mean TVC on the

cleared brisket was the same as that on the knife before use. ESAM sampling yielded mean TVC 1 $\log_{10}$ greater than that of the cleared tissue following legging or brisket clearing, and 0.5 $\log_{10}$ greater than the exposed tissue following bunging. Similarly, the ESAM samples were more often contaminated with *E. coli* or *S. aureus* than the exposed tissue samples taken at each dressing station. This suggests that much of the contamination carried by the resultant carcase is picked up later in the process, from other workers or from airborne contamination.

7 FURTHER WORK

As there was no apparent relationship between the operations at each individual dressing station and the final microbial load on the carcases at ESAM sampling, further work is needed to elicit the true sources of this contamination.

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