PPI

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INDUSTRY SUMMARY

Over a 15-month period, this study has evaluated a range of livestock and carcase slaughter and dressing procedures in relation to carcase macro- and micro-contamination levels. This summary provides a brief review of the key findings from this study and makes recommendations for further investigations.

The study was undertaken at four bovine processing establishments (2 upward and 2 downward hide pullers) and four ovine processing establishments (2 export and 2 domestic).

Livestock factors were a major contributor to final carcase microbial loads for both bovines and ovines. Associations between procedure score, macro- and micro-contamination were strongest in the ovine processing establishments.

Livestock Factors

Microbial loads on the hides and pelts of bovine and ovine carcases being processed had the strongest association with final carcase microbial counts. On average, hide/pelt microbial counts and therefore carcase microbial counts were greatest during the winter and spring months. Factors contributing to higher hide/pelt microbial counts are summarised in the following table.

Livestock Factors Contributing to Higher Carcase Microbial Loads

Factor	Bovine	Ovine
Hairy hide/wool length >5cm	Higher TVC, Coliforms, *E.coli*	Higher TVC, Coliforms, *E.coli*
Daggy hide/non-crutched pelt	Higher TVC, Coliforms, *E.coli*	Higher Coliforms, *E.coli*
Age (Dentition)	No consistent trend	Higher TVC, Coliforms, *E.coli*
Travel distance >200km	Higher TVC, Coliforms, *E.coli*	Higher TVC, Coliforms, *E.coli*
Saleyard purchase	No consistent trend	Higher TVC, Coliforms, *E.coli*

For bovines, there were no apparent differences between grain and grass fed cattle (although all grain fed cattle in this study were short fed) or between males and females.

For ovines, any effect of sex or mulesing could not be measured. The presentation of ovines with dirty or dusty pelts did not appear to have a detrimental effect on carcase microbial contamination. Length of pelt was more relevant.

Recommendation 1: That beef producers be encouraged to supply livestock for slaughter that are clean (minimal dirt/faecal material) and have short hair coats[+].

Recommendation 2: That sheep and lamb producers be encouraged to supply livestock for slaughter that are shorn (less than 5cm pelt) and crutched to remove all visible dags.

[+] The difficulty associated with producers being able to supply cattle with short hair coats throughout the year is noted.

Recommendation 3: That meat processing establishments be encouraged to purchase livestock on direct to works consignment.

Procedures

The data presented in this report supports the common industry held perception that slaughter and dressing procedures are better in bovine processing than ovine processing establishments. However, there was one ovine processor that consistently achieved lower procedure scores than any bovine processor in this study.

The procedure scoring system implemented by Alliance in this study provided for quantification of slaughter and dressing procedures and therefore provides for tracking over time. All establishments in this study were simply checking if procedures were being undertaken correctly at any point in time, rather than attempting to measure changes over time.

Procedure score was closely associated with carcase Coliforms and *E.coli* loads in the ovine processing establishments.

Improving procedure scores within an establishment over time did not lead to lower carcase macro or micro-contamination. Differences were observed between establishments, suggesting that substantial changes in procedure score are required before improved micro-contamination levels can be realised. Differences in average total microbial carcase counts between the best and worst procedure score bands amounted to 0.72 $\log_{10}$ for bovines and 0.77 $\log_{10}$ for ovines.

We suspect that some processors may currently be requested to implement 'costly' procedural changes that may have a small real effect, if any, on overall carcase microbial loads. This does not take away from the need for all processors to achieve an industry standard and quantifiable procedure score.

There was a tendency for bovine carcases processed in establishments with downward hide pullers to record higher microbial counts than those processed with upward hide pullers.

On average, domestic ovine processing establishments recorded higher procedure scores, macro-contamination scores and carcase microbial counts.

Recommendation 4: That the industry implement a system for the quantification of procedure scores. This system would enable an industry benchmark to be set for all processors. Procedural improvements should not be mandated for processors meeting or exceeding the benchmark.

Macro-contamination Scores

Alliance developed and used a system for macro-contamination scoring that was based on the ARMCANZ and AQIS carcase hygiene assessments that provided for cumulative carcase scores based on scoring 3 regions on a bovine carcase side and 5 regions on an ovine carcase. Carcases were scored prior to trimming and washing and then again following trimming and washing.

We suspect the bovine processors in this study have reached a level of 'diminishing returns' with respect to macro-contamination scoring in that there is little or no improvement to be made in carcase microbial loads through increased attention to improving carcase macro-contamination levels under the existing AQIS or ARMCANZ Meat Hygiene Assessment Systems. Assuming a given level of livestock cleanliness, a 'break through' technology would be required to have a significant impact on carcase microbial loads. Of course, any plants operating outside these levels would have a requirement to get their macro-contamination scores down.

In their attempt to achieve extremely low carcase macro-contamination levels after trimming and washing, we observed bovine processors recorded higher microbial loads after corrective action than prior to trimming and washing. This suggests attempts to remove 'minimal' macro-contamination may actually lead to increased micro-contamination.

A similar finding to that reported for bovine processors was observed for export establishments processing ovine carcases in that microbial levels appeared to be higher after corrective action (ie, after trimming and washing; average increase 0.10 $\log_{10}$ for export and – 0.15 $\log_{10}$ for domestic).

Recommendation 5: That the approach to Carcase Hygiene Assessment be modified to reflect the relationship between macro-contamination scores and carcase microbial contamination. Establishments able to achieve the existing industry standard under AQIS or ARMCANZ should be allowed to undertake reduced levels of monitoring (ie, 3 x day → daily → weekly → monthly etc) based on their audit performance.

Other Findings

- Data collected from one establishment demonstrates an increase in the level of microbial contamination of bovine carcases with time in the chiller but no difference over time for ovine carcases.
- Bovine carcase sites consistently recording higher than average microbial counts include the outside, foreshank and brisket.
- Ovine carcase sites consistently recording higher than average microbial scores include the flank, foreshank, brisket, rib and shoulder.

Further Research

This study has drawn attention to a number of issues that warrant further investigation. These include:

1. The relative effect of carcase washing versus 'dry' dressing procedures on carcase microbial contamination. A positive outcome could lead to substantial cost reductions for meat processing establishments through water saving.

2. A closer investigation of some of the livestock factors which were not fully evaluated in this study, namely:
   - Grain versus grass feeding for bovines, particularly for long fed cattle
   - Broad breed type comparisons for ovines and bovines.
3. Establishment of a pathogen risk determination system for meat processing establishments based on a GIS model incorporating seasonal, geographical, spatial and livestock databases.

1. INTRODUCTION

This report presents the final findings for slaughterfloor procedures, carcase hygiene (macro-contamination score) and microbiological status measured at participating establishments on six separate occasions from December 1996 to March 1998.

The objectives of this study were to:

1. Establish microbiological profiles on bovine and ovine carcases at critical points of the slaughter and dressing process
2. Correlate the findings with major processing modes and new process developments
3. Study the influence of livestock status on hygienic output
4. Study the influence of personnel-related factors on hygienic output
5. Recommend best practice methods in slaughter and dressing to minimise bacterial contamination and their incorporation into enterprise HACCP based QA systems.

2. METHODOLOGY

Four bovine processing and four ovine processing establishments were involved in this study. The bovine establishments comprised two northern and two southern plants while the ovine establishments were all located in southern Australia and comprised two export and two domestic plants.

2.1 PROCEDURE SCORE

With respect to hygienic slaughter and dressing, procedures were scored at each work station from sticking to evisceration. Provision in this score was made for equipment faults that compromised carcase hygiene. The scoring system used and a listing of hygienic procedures are provided in Annex 1. Ten randomly selected carcases were scored for hygienic procedures at each workstation. Where more than one slaughterman was involved at a single workstation, the procedure score was averaged for all slaughtermen performing that task.

2.2 SLAUGHTERFLOOR MACRO-CONTAMINATION SCORE

Twenty carcases were scored for the following macro-contaminates: hair/wool, hide/skin, faeces, ingesta and other contamination (ie, dust, dirt and grease). For bovine carcases, contamination was scored in three areas of the carcase: hindquarter, forequarter and internally; for ovine carcases, contamination was scored in five areas of the carcase: hind-back, hind-front, fore-back, fore-front and internally. The scoring was carried out after hide or skin removal but before any trimming or washing of the carcase to ensure procedures were measured rather than the efficiency of any corrective action. For some establishments this necessitated scoring of carcase areas at different workstations. Each area was scored for each

contamination type on a 0-3 scoring system, where 0 represented no contamination and 3 represented gross contamination. The scoring system is detailed in Annex 2.

2.3 CHILLER MACRO-CONTAMINATION SCORE

Macro-contamination was recorded after final trimming and washing on the 20 carcases selected in 2.4. Chiller macro-contamination scores provide an indication of the effectiveness of corrective action (trimming and carcase washing) being undertaken at each plant. The scoring system is detailed in Annex 2.

2.4 MICROBIOLOGICAL

Sponge swab samples from three sites (brisket, flank and topside) of approximately 100cm^2 were collected from each of 20 carcases prior to hide/skin removal; after hide/skin removal and evisceration but prior to trimming and washing; and, after trimming and washing. They were placed in a sterile bag and sent by overnight courier to a laboratory where the following microbiological tests were undertaken:

- Total Plate Count (TPC) - total bacteria present (cfu per cm^2)
- Coliform Count - total coliform bacteria present (cfu per cm^2)
- *E coli* Count - total *E coli* bacteria present (cfu per cm^2)

No attempt was made to identify specific *E coli* strains.

2.5 SITE DATA

An analysis was undertaken of carcase microbial data supplied from two bovine and two ovine processing establishments. This analysis provides comparison with the data collected within this study and provides additional results.

3. PROGRESS RESULTS

3.1 HACCP TEAMS

All sites had implemented HACCP as part of their QA system and in all instances we worked closely with the HACCP team leader at each site. HACCP Monitor software was installed at all sites although was only used to its fullest extent in two ovine and one bovine establishment. The other sites had developed their own internal systems for regular reporting of their monitoring programs. In some instances, the respective HACCP team leader supplied additional data to us. These data are reported later (section 3.4).

3.2 BOVINES

3.2.1 Procedure score

Figure 1 shows average procedure scores have fluctuated over the 12 months of this study but, on average, have trended upwards since December 1996. As shown in Figure 1, however, one establishment (Estab 3) has shown continuous improvement over the 15-month period. Procedure scores were not obtained from establishment 2 in March 1998.

FIGURE 1: PROCEDURE SCORE BY BOVINE ESTABLISHMENT OVER TIME
(Lower scores indicate best procedures)

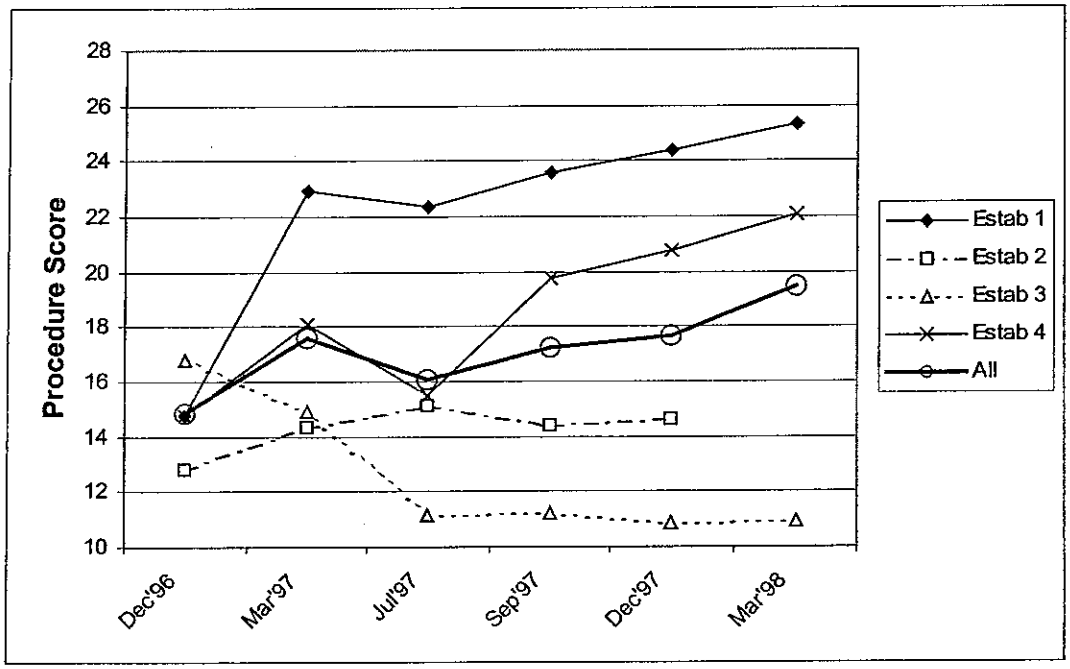


Figure 2 provides an examination of procedure score by workstation. Stations with consistently poor procedure scores were; sticking, weasand rod and tie, head removal, opening of the hind leg, bunging, removal of forelegs, hide removal and gut/pluck removal.

Figure 3 indicates procedure scores could be improved if two knife sanitisation was introduced at all sites and/or slaughtermen paid greater attention to hand washing and sanitising knives after steeling and/or pouching and avoiding 'cutting down' through the hide rather than using 'spear cuts'. However, argument can be made for and against introduction of these processes based on the net effect these practices may have on carcase micro-contamination (refer section 3.2.3.4).

As discussed in section 3.2.3.4, large changes in procedure score are required for changes in carcase macro- and micro-contamination to be realised. The correlation between procedure score and micro-contamination of carcases in this study was small ($R=0.37$, $p<0.05$). Slightly higher correlations were recorded between procedure score and macro-contamination levels prior to ($R=0.59$, $p<0.001$) and after trimming and washing ($R=0.67$, $p<0.001$).

FIGURE 2: PROCEDURE SCORE BY WORKSTATION
(Lower scores indicate best procedures)

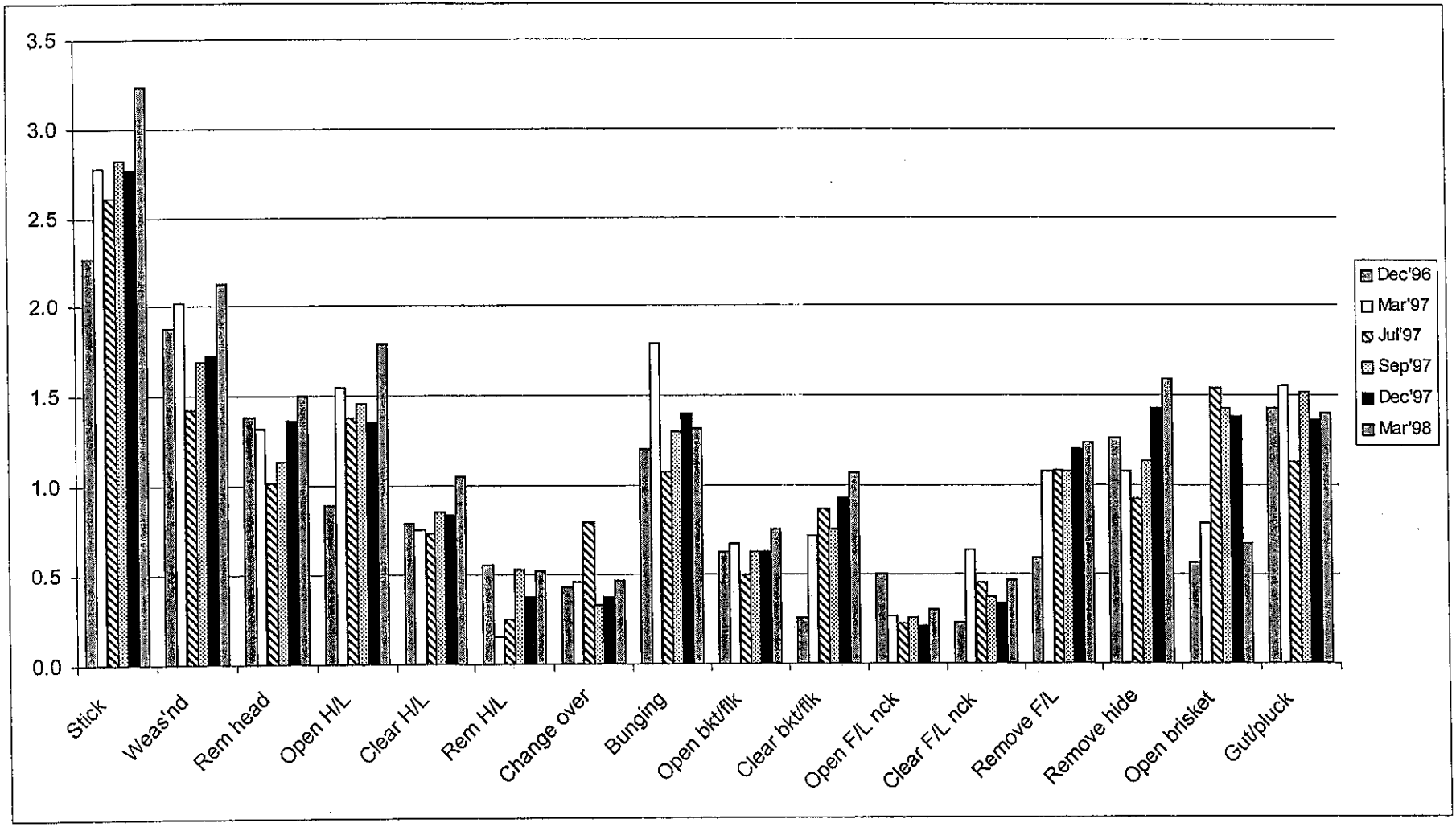
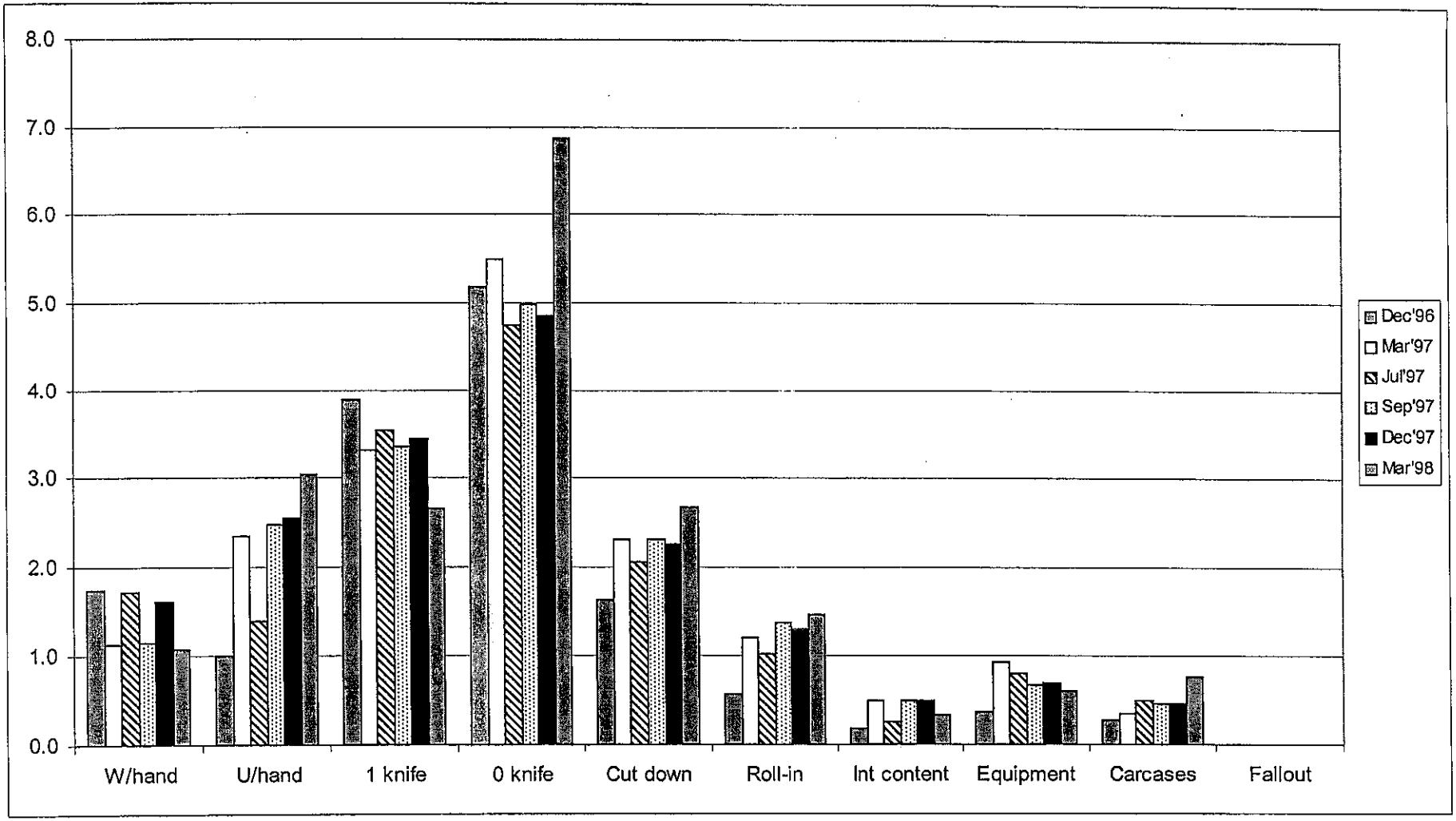


FIGURE 3: PROCEDURE SCORE BY PROCEDURE TYPE (LOWER SCORES INDICATE BEST PROCEDURES)



3.2.2 Macro-contamination score

As shown in Figure 4, macro-contamination scores prior to (SF) and after trimming and washing (CH) were highest during the winter and spring months.

Figures 5 and 6 show the macro-contamination scores of individual establishments prior to and after trimming and washing respectively. Although trends in macro-contamination scores have not followed trends in procedure score we did record small correlations between procedure score and macro-contamination score prior to ($R=0.59$, $p<0.001$) and after trimming and washing ($R=0.67$, $p<0.001$) of carcases. There was no correlation between macro-contamination score and micro-contamination levels of carcases in the chiller. We did, however, observe differences in the level of micro-contamination of carcases at relatively high macro-contamination levels. This is discussed further in section 3.2.3.4.

FIGURE 4: MACRO-CONTAMINATION PRIOR TO (SLAUGHTERFLOOR) AND AFTER (CHILLER) TRIMMING AND WASHING
(Lower scores indicate less macro-contamination)

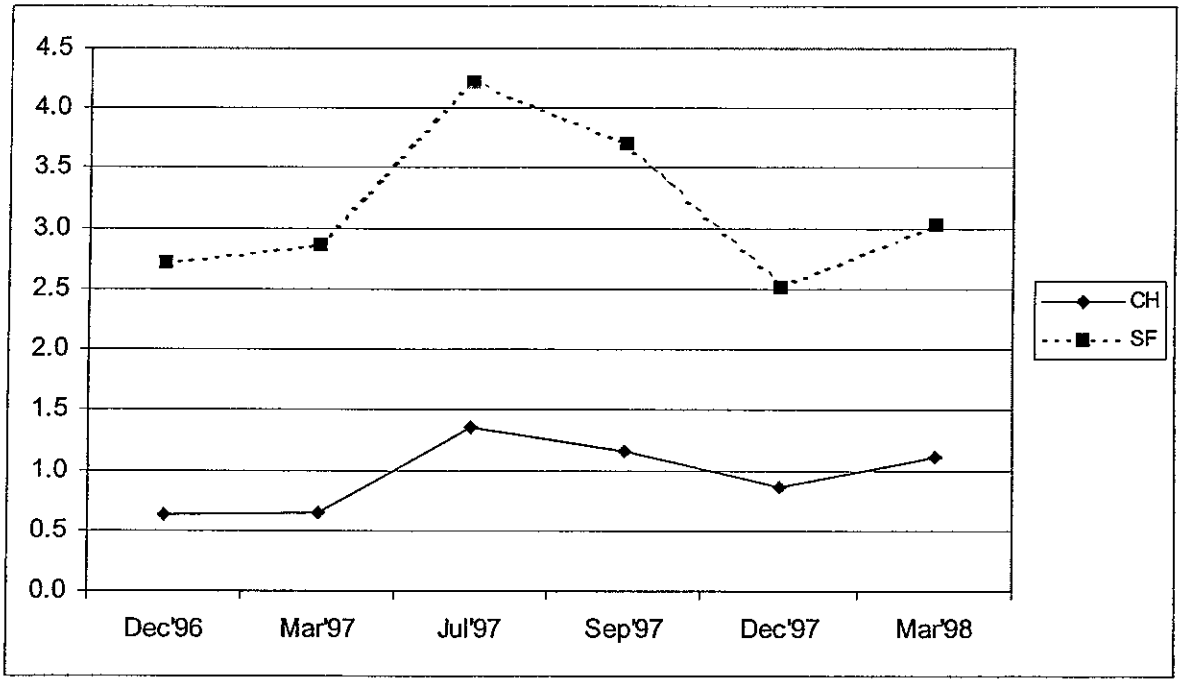


FIGURE 5: ESTABLISHMENT MACRO-CONTAMINATION PRIOR TO TRIMMING AND WASHING
(Lower scores indicate less macro-contamination)

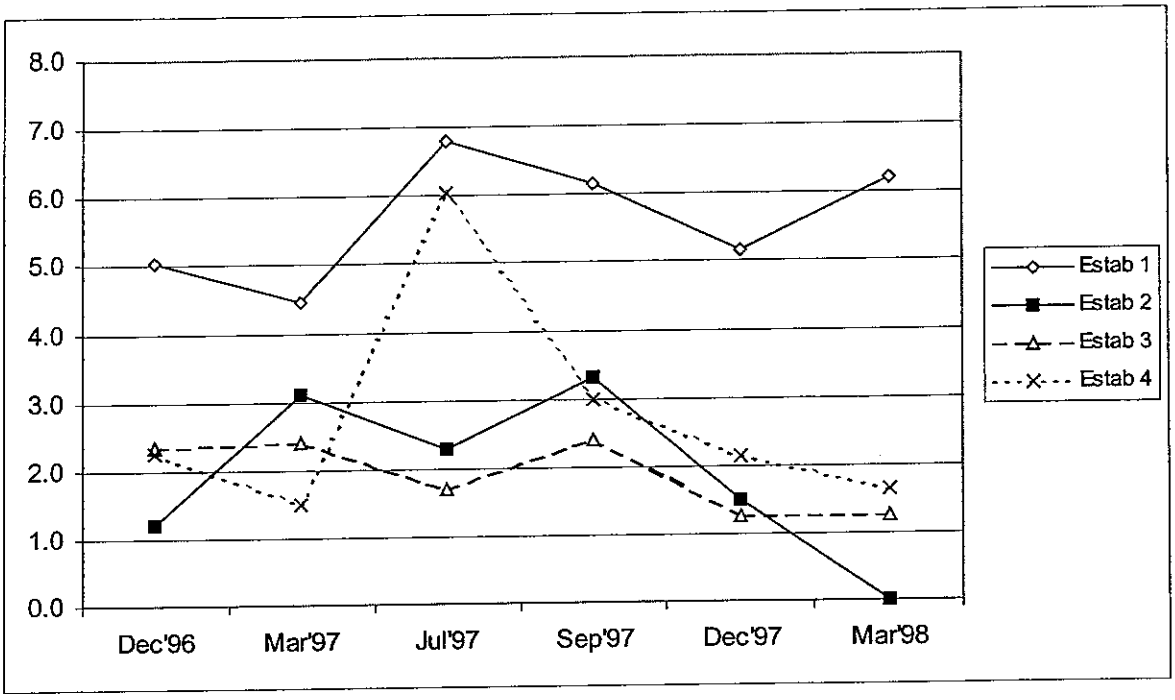
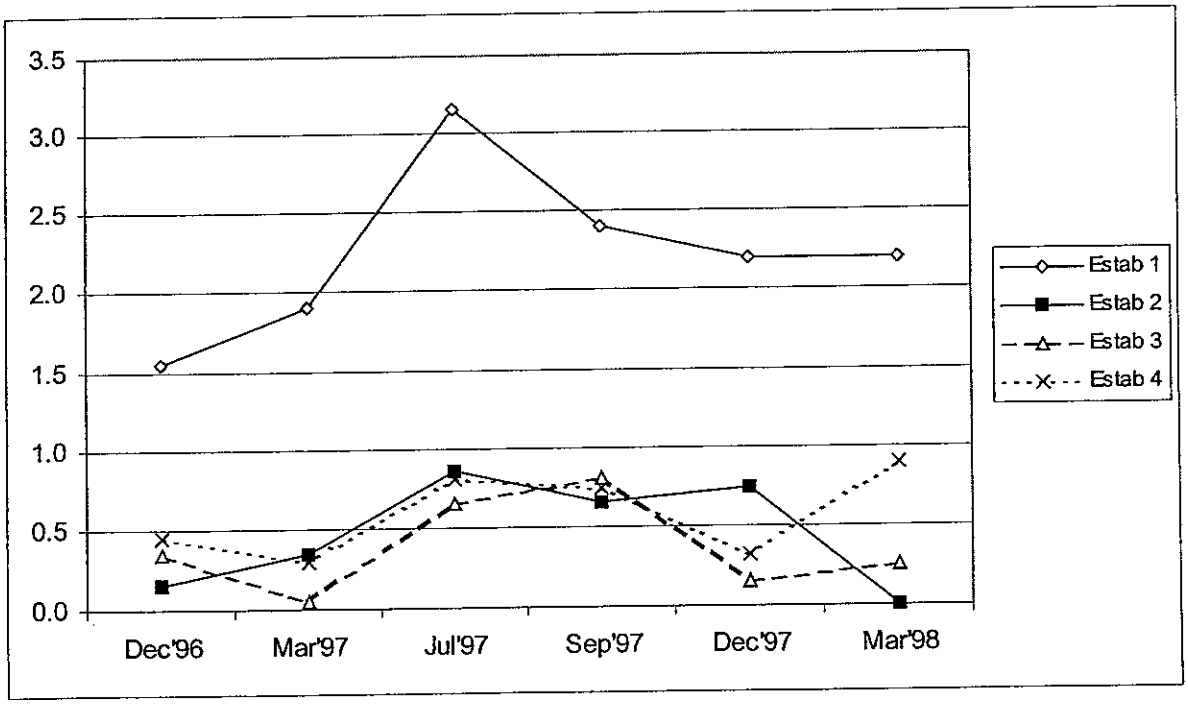


FIGURE 6: MACRO-CONTAMINATION AFTER TRIMMING AND WASHING
(Lower scores indicate less macro-contamination)



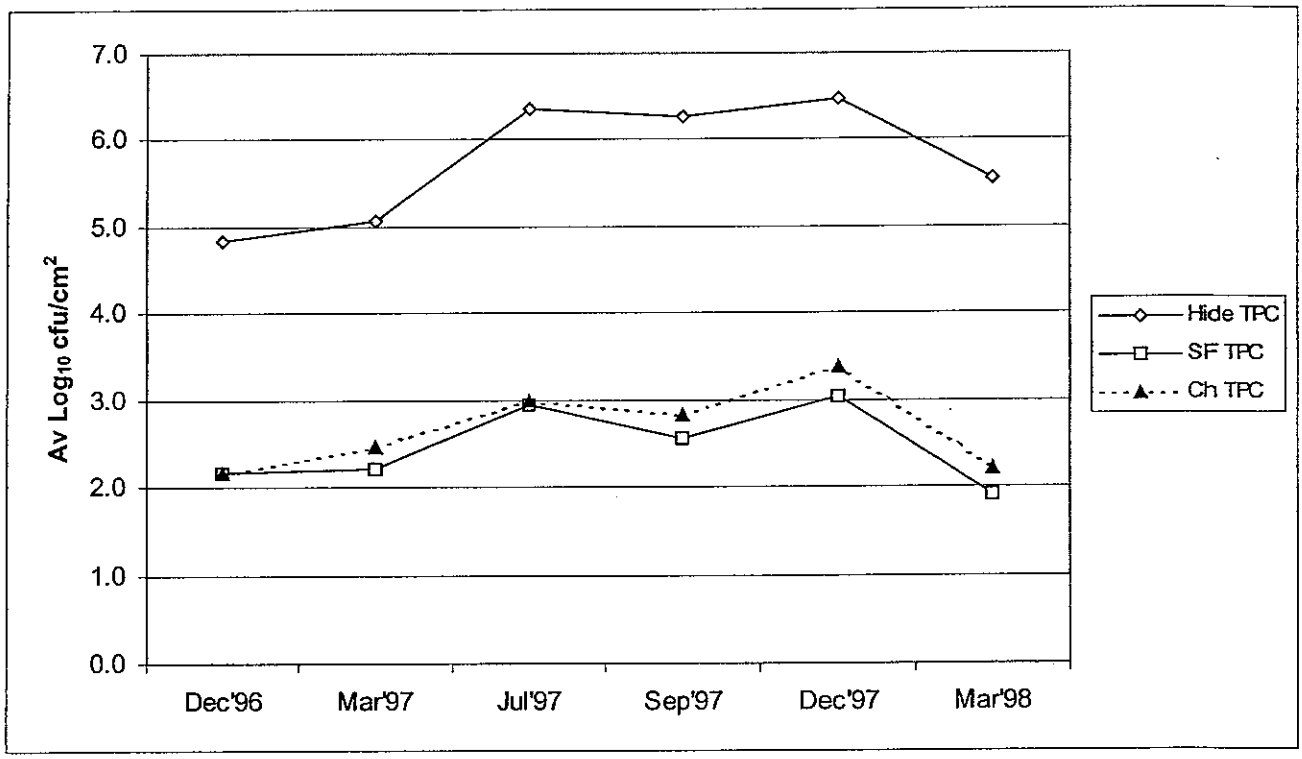
3.2.3 Microbial scores

3.2.3.1 Total aerobic plate count

Mean aerobic plate counts for 'hide on' (Hide TPC), 'prior to trim and wash' (SF TPC) and 'after trimming and washing' (CH TPC) are shown for all establishments in Figure 7 and for individual establishments in Figure 8. Microbial results were not obtained for establishment 1 in September 1997 and for establishment 2 in March 1998. The main findings were:

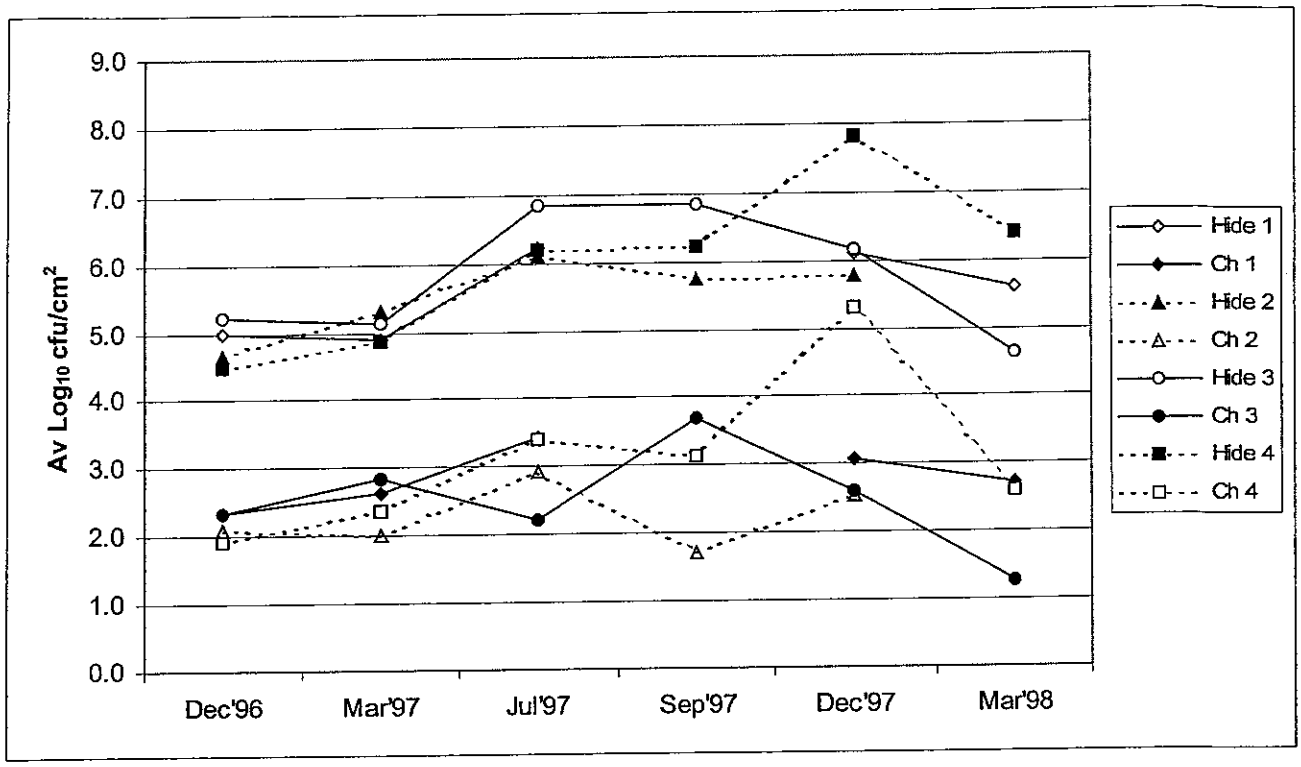
- The highest microbial loads were recorded from hides (average 10^4 to 10^7 cfu[†] per cm^2) with carcase microbial counts generally below 10^4 cfu per cm^2
- Carcase microbial loads (SF TPC & Ch TPC) closely followed the microbial load level of the bodies being processed (Hide TPC) over time
- Microbial loads after trimming and washing (mean log=2.68, sd=1.040) have tended to be higher ($p<0.001$) than prior to any corrective action (mean log=2.49, sd=1.110). This suggests attempts to remove all macro-contamination may be adding to carcase microbial loads and/or the process of washing may be more evenly distributing total carcase microbial load over the carcase.

FIGURE 7: AVERAGE TOTAL AEROBIC PLATE COUNTS OVER TIME



[†] Cfu = Colony forming unit

FIGURE 8: TOTAL AEROBIC PLATE COUNTS BY ESTABLISHMENT



Regression analysis confirms carcase microbial loads are most closely related to the hide microbial loads of animals being slaughtered. Factors that may contribute to total carcase microbial loads are shown in Table 1.

TABLE 1: FACTORS INFLUENCING CARCASE MICROBIAL CONTAMINATION

Factor	No.	Mean log TVC (sd) Hide	Carcase Pre-trim/Wash	Carcase Post-trim/Wash
Hide Dirt				
- Clean	380	5.61 (0.913)	2.37 (1.017)	2.59 (0.970)
- Dirty	60	6.56 (0.758)	3.28 (1.340)	3.26 (1.267)
		(p<0.001)	(p<0.001)	(p<0.001)
Hide Hair				
- Short	184	5.36 (0.789)	2.24 (0.881)	2.37 (0.771)
- Long	256	6.01 (0.962)	2.67 (1.219)	2.91 (1.147)
		(p<0.001)	(p<0.001)	(p<0.001)
Dentition				
- 0 tooth	162	5.59 (0.810)[a]	2.43 (1.147)	2.58 (0.920)[a]
- 2 tooth	92	5.85 (1.083)[b]	2.59 (1.231)	2.95 (1.276)[b]
- 4-7 tooth	69	5.36 (1.008)[a]	2.49 (1.041)	2.51 (0.989)[a]
- 8 tooth	57	5.92 (1.010)[b]	2.74 (1.074)	3.07 (1.018)[b]

Factor	No.	Mean log TVC (sd) Hide	Carcase Pre-trim/Wash	Carcase Post-trim/Wash
Transport				
- single deck	24	5.03 (0.517)	2.23 (0.554)	2.46 (0.502)
- double deck	76	6.08 (0.848)	2.66 (0.779)	3.22 (0.901)
		(p<0.001)	(p<0.05)	(p<0.001)
Travel Distance				
- 1-200 km	139	5.25 (0.780)	2.33 (0.850)	2.58 (0.837)
- 200+ km	145	5.87 (0.902)	2.58 (0.951)	2.66 (0.900)
		(p<0.001)	(p<0.05)	(ns)

a,b,c – Within a cell, means with differing subscripts differ significantly (p<0.05)

Eighty three per cent of all cattle with dirty hides were also scored as hairy while 20% of hairy cattle were also dirty.

Total carcase microbial loads (pre or post trim/wash) did not differ between:

- males and females
- breed type (*B.taurus, B.indicus* or their crosses)
- grain and grass fed cattle
- cattle bought out of the saleyard or direct to works
- carcases processed by works with upward or downward hide pullers.

Differences in carcase microbial counts between age groups reported in Table 1 (Dentition) appeared to be related to microbial hide counts rather than any specific age difference.

3.2.3.2 Hide Coliform/*E.coli* counts

Average carcase Coliform counts ranged from 145 cfu/cm^2 in December 1996 to 2,209 cfu/cm^2 in July 1997 (Figure 9). *E.coli* counts ranged from 12 cfu/cm^2 in December 1996 to 1,609 cfu/cm^2 in March 1998.

3.2.3.3 Carcase Coliform/*E Coli* counts

As shown in Figure 10, average carcase Coliform counts have not exceeded 6.5 cfu/cm^2 (December 1997). Carcase *E.coli* counts have never exceeded an average of 4.5 cfu/cm^2 (December 1997).

FIGURE 9: AVERAGE HIDE COLIFORM/*E.COLI* COUNTS OVER TIME

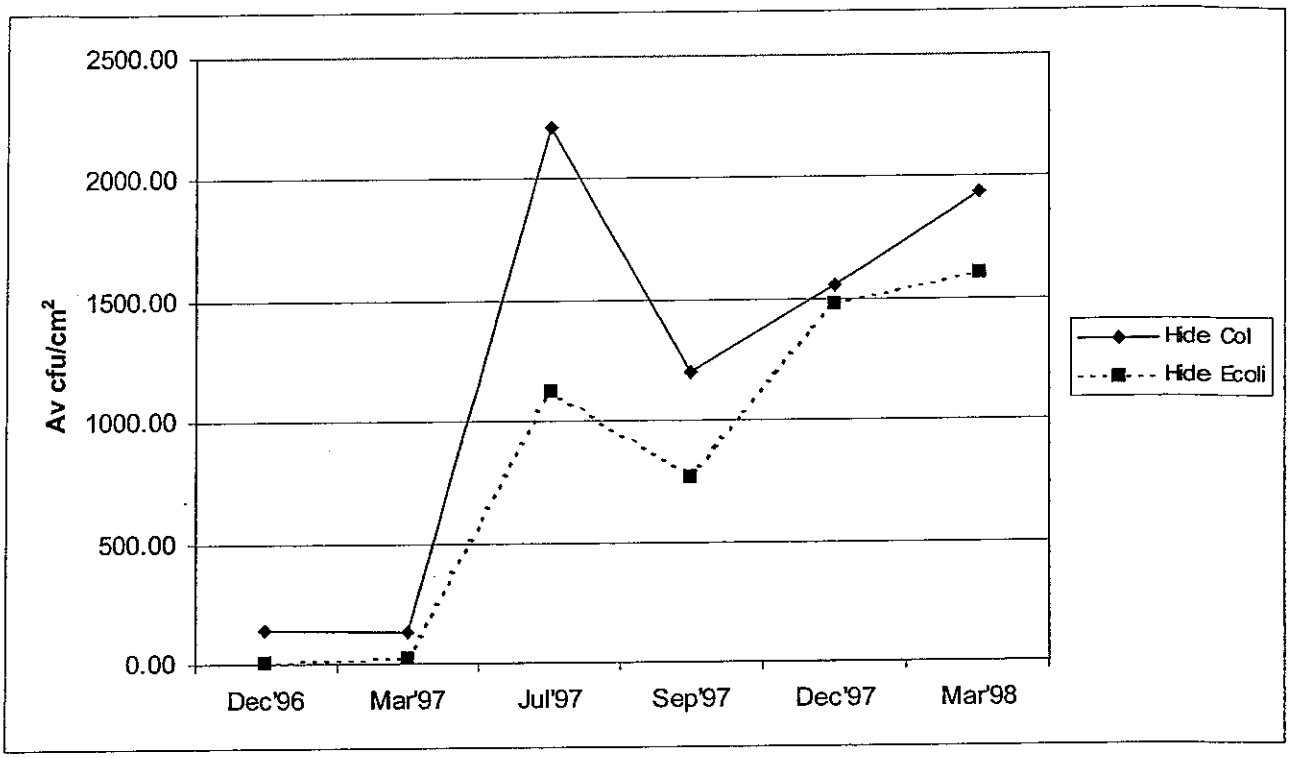
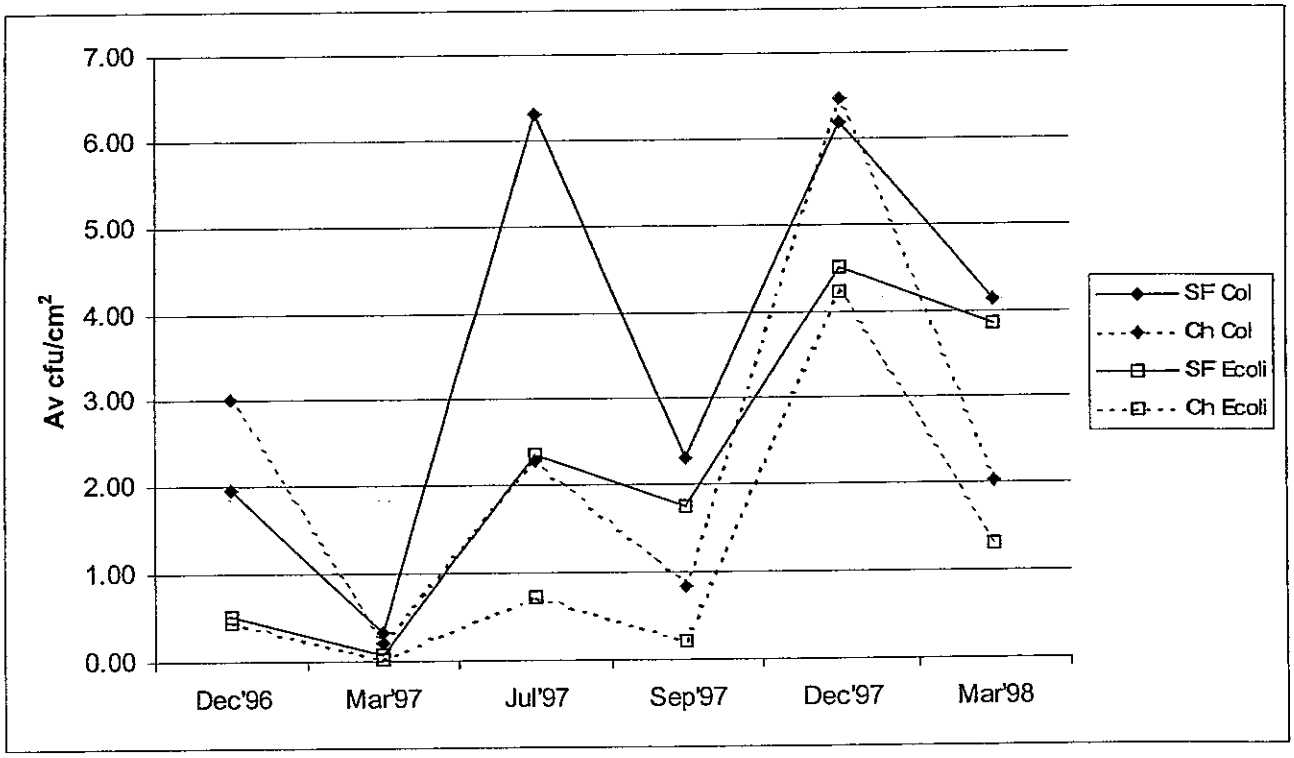


FIGURE 10: AVERAGE CARCASE COLIFORM/*E COLI* COUNTS PRIOR TO (SF) AND AFTER (CH) TRIMMING AND WASHING



Regression analysis showed carcase Coliform and *E.coli* loads were directly related to hide puller type and cattle breed respectively. Factors that may contribute to carcase Coliform and *E.coli* loads are shown in Tables 2 and 3 respectively.

TABLE 2: FACTORS INFLUENCING CARCASE COLIFORM CONTAMINATION

Factor	No.	Mean Coliform Count – cfu/cm^2 (sd)		
		Hide	Carcase	
			Pre-trim/Wash	Post-trim/Wash
Hide Dirt				
- Clean	380	1027 (1267.5)	3.1 (6.57)	2.2 (5.53)
- Dirty	60	2032 (1270.9)	6.3 (8.35)	4.9 (7.75)
		(p<0.001)	(p<0.01)	(p<0.05)
Hide Hair				
- Short	184	667 (1086.3)	2.4 (5.80)	1.7 (4.75)
- Long	256	1521 (1346.7)	4.4 (7.51)	3.2 (6.61)
		(p<0.001)	(p<0.01)	(p<0.01)
Dentition				
- 0 tooth	162	1145 (1318.1)	2.6 (5.85)^a	1.8 (4.66)^a
- 2 tooth	92	1261 (1354.4)	4.6 (7.46)^b	3.2 (6.70)^b
- 4-7 tooth	69	1014 (1335.3)	4.6 (8.3)^{ab}	3.1 (6.68)^{ab}
- 8 tooth	57	1318 (1290.5)	5.3 (8.25)^b	5.3 (8.43)^b
Breed				
- *B.taurus*	344	1070 (1267.8)^a	2.9 (6.35)^a	1.8 (4.72)^a
- *B.indicus*	30	1062 (1409.5)^a	7.2 (9.08)^b	7.5 (9.71)^b
- *BT x BI*	66	1696 (1389.6)^b	5.1 (7.91)^b	4.6 (7.76)^c
Travel Distance				
- 1-200 km	165	881 (1156.7)	2.7 (6.50)	1.3 (4.01)
- 200+ km	259	1319 (1382.3)	4.2 (7.23)	3.5 (6.90)
		(p<0.001)	(p<0.05)	(p<0.001)

a,b,c – Within a cell, means with differing subscripts differ significantly (p<0.05)

TABLE 3: FACTORS INFLUENCING CARCASE *E.COLI* CONTAMINATION

Factor	No.	Mean *E.coli* Count – cfu/cm^2 (sd) Hide	Carcase Pre-trim/Wash	Carcase Post-trim/Wash
Hide Dirt				
- Clean	380	705 (1129.1)	1.8 (4.83)	1.0 (3.56)
- Dirty	60	1434 (1327.7)	3.9 (6.88)	2.4 (4.95)
		(p<0.001)	(p<0.05)	(p<0.05)
Hide Hair				
- Short	184	529 (1010.2)	1.5 (4.54)	0.7 (2.86)
- Long	256	1003 (1258.6)	2.6 (5.59)	1.6 (4.32)
		(p<0.001)	(p<0.05)	(p<0.05)
Dentition				
- 0 tooth	162	781 (1181.4)	1.6 (4.42)^a	0.8 (2.79)^a
- 2 tooth	92	841 (1238.9)	3.2 (6.36)^b	1.7 (4.85)^{ab}
- 4-7 tooth	69	707 (1172.2)	2.3 (5.70)^{ab}	1.1 (3.44)^a
- 8 tooth	57	1062 (1267.3)	2.9 (6.11)^{ab}	2.6 (5.85)^b
Breed				
- *B.taurus*	344	668 (1068.5)^a	1.6 (4.33)^a	0.5 (2.04)^a
- *B.indicus*	30	909 (1392.4)^a	3.2 (6.73)^{ab}	4.6 (7.63)^b
- *BT x BI*	66	1468 (1419.8)^b	4.3 (7.51)^b	3.1 (6.20)^b
Travel Distance				
- 1-200 km	165	597 (1021.9)	1.4 (4.30)	0.6 (2.35)
- 200+ km	259	919 (1258.1)	2.6 (5.69)	1.7 (4.53)
		(p<0.01)	(p<0.05)	(p<0.01)

a,b,c – Within a cell, means with differing subscripts differ significantly (p<0.05)

Carcase Coliform/*E.coli* loads (pre or post trim/wash) did not differ between:

- males and females
- grain and grass fed cattle
- cattle bought out of the saleyard or direct to works
- single or double deck cattle transport trucks

3.2.3.4 Relationship between Procedure Score, Macro- and Micro-Contamination on Bovine Carcases

Table 4 provides the comparisons between procedure score, macro-contamination scores and total micro-contamination levels of bovine carcases in this study. Similar trends, although non-significant differences ($p>0.05$) were also observed between procedure score, macro-contamination scores and Coliform or *E.coli* contamination levels of bovine carcases in this study. To compare the macro-contamination scores with AQIS Meat Hygiene Assessments, the following should be used as a guide:

Alliance Score	AQIS MHA
0	No observable contamination
1	Minor defect
2	Major defect
3	Critical defect

Alliance scores were cumulative across macro-contamination type and area on the carcase. Therefore individual carcase scores could exceed '3' depending on the level of macro-contamination over the carcase (see section 2).

TABLE 4: COMPARISON BETWEEN TOTAL MICROBIAL CONTAMINATION AND MACRO-CONTAMINATION AND PROCEDURE SCORES

Factor	No.	Mean log TVC (sd) Hide	Carcase Pre-trim/Wash	Carcase Post-trim/Wash
Procedure Score				
- 0-12	80	6.12 (1.064)[a]	1.79 (0.970)[a]	2.43 (1.091)[a]
- 12.1-15	140	5.16 (0.625)[b]	2.38 (0.873)[b]	2.21 (0.752)[a]
- 15.1-18	60	5.83 (0.503)[a]	2.71 (1.023)[c]	2.88 (0.667)[b]
- 18.1+	160	6.02 (1.019)[a]	2.85 (1.213)[c]	3.15 (1.126)[b]
Pre-trim/wash Macro Score				
- 0-1	149	5.78 (1.073)	2.36 (1.244)[a]	2.64 (1.197)[ab]
- 2-3	138	5.66 (0.900)	2.36 (1.063)[a]	2.52 (0.925)[a]
- 4-5	80	5.81 (0.923)	2.54 (0.919)[ac]	2.79 (1.019)[ab]
- 6-7	44	5.83 (0.778)	2.91 (0.976)[bc]	2.94 (0.945)[b]
- 8+	29	5.56 (0.827)	3.02 (1.008)[b]	2.99 (0.713)[b]
Post-trim/wash Macro Score				
- 0	235	5.65 (1.017)[a]	2.41 (1.224)[a]	2.61 (1.136)[a]
- 1	101	5.86 (0.859)[ab]	2.46 (0.928)[a]	2.71 (0.955)[ab]
- 2	52	5.70 (0.868)[ab]	2.58 (0.858)[ab]	2.64 (0.818)[ab]
- 3	32	5.81 (0.903)[ab]	2.78 (1.116)[ab]	3.05 (0.988)[b]
- 4+	17	6.17 (0.685)[b]	3.08 (0.988)[b]	2.86 (0.789)[ab]

a,b,c – Within a cell, means with differing subscripts differ significantly ($p<0.05$)

It appears from Table 4 that procedure scores in excess of 15 are required before any difference in carcase microbial contamination is detected. Macro contamination scores exceeding an average carcase score of '4' pre-trim and wash and score '3' post trim and wash were required before any detrimental effect on carcase microbial contamination was observed. This equates to every carcase scoring at least one critical defect under the AQIS or ARMCANZ Meat Hygiene Assessment systems and is therefore far greater than currently allowed under these systems.

Based on our findings presented in Table 4 we would propose that the AQIS or ARMCANZ Meat Hygiene systems may be operating in too narrow a range for changes in macro-contamination to have any real effect on micro-contamination of bovine carcases. It would therefore appear unnecessary to undertake extensive daily monitoring if an establishment could demonstrate it was operating below certain standards. With respect to the Alliance scoring system used in this study, this would apply to those establishments demonstrating procedure scores below 15, pre-trim macro-contamination scores below 4 and post-trim macro-contamination scores below 3. Reduced levels of monitoring would then be acceptable. Of course, suitable recognition would need to be made of overseas country requirements (eg, zero tolerance in the USA), although a scientific argument could be mounted to counter what appears to be a non-productive requirement based on the results presented here.

3.2.3.5 Bovine Processing Technology

Table 5 provides a comparison of procedure scores, macro-contamination scores and microbial loads on carcases processed in establishments with either upward or downward hide puller technology. Despite higher average procedure and macro-contamination scores being recorded in plants with upward hide pullers than downward hide pullers, lower average carcase microbial loads were recorded.

3.2.4 Cattle Observations

The following observations are based on the data obtained from this study:

1. Microbial loads on the hides of carcases being processed had the strongest association with final carcase microbial counts. On average, hide microbial counts and therefore carcase microbial counts were greatest during the winter and spring months
2. Improving procedure scores within an establishment has not led to lower carcase macro or micro-contamination. In this study, procedure scores needed to exceed score 15 for any detrimental effect on carcase microbial load to be detected
3. We suspect the bovine processors in this study have reached a level of 'diminishing returns' with respect to macro-contamination scoring in that there is little or no improvement to be made in carcase microbial loads through continued focus on improving carcase macro-contamination levels under the existing AQIS or ARMCANZ Meat Hygiene Assessment Systems. A 'break through' technology would be required to

have a significant impact on carcase microbial loads for these processors. Of course, any plants operating outside these levels would have a requirement to get their macro-contamination scores down

4. Higher microbial loads after corrective action suggest attempts to remove 'minimal' macro-contamination may actually lead to increased micro-contamination
5. Establishments with upward hide pullers appear to have lower carcase microbial counts than those with downward hide pullers
6. Delivery of clean cattle with shorthaired coats is likely to have the biggest impact on reducing macro and micro-contamination of carcases during slaughtering and dressing
7. The longer the travel distance (greater than 200km), the greater the final carcase microbial load
8. There was a tendency for carcases processed in establishments with downward hide pullers to record higher Coliform and *E.coli* counts than those processed with upward hide pullers
9. Cattle with *B.indicus* content recorded higher Coliform and *E.coli* counts than *B.taurus* cattle.

TABLE 5 : RELATIONSHIP BETWEEN PROCESSING TECHNOLOGY, PROCEDURE, MACRO- AND MICRO-CONTAMINATION SCORES

Score Mean (sd)	Upward Puller (n=220)	Downward Puller (n=220)	Significance Level
Procedure Score	17.4 (5.64)	16.6 (2.95)	$p<0.05$
Hide Microbial Load			
- TVC (log_{10} cfu/cm^2)	5.70 (0.912)	5.78 (0.986)	ns
- Coliforms (cfu/cm^2)	1237 (1334.1)	1090 (1289.8)	ns
- *E.coli* (cfu/cm^2)	798 (1160.5)	811 (1208.3)	ns
Pre-trim/Wash			
- Macro-contamination score	3.8 (2.86)	2.5 (2.17)	$p<0.001$
- TVC (log_{10} cfu/cm^2)	2.30 (1.026)	2.68 (1.160)	$p<0.001$
- Coliforms (cfu/cm^2)	2.5 (5.43)	4.7 (7.99)	$p<0.01$
- *E.coli* (cfu/cm^2)	1.6 (4.24)	2.6 (5.97)	$p<0.05$
Post-trim/Wash Microbial Load			
- Macro-contamination score	1.3 (1.56)	0.6 (0.87)	$p<0.001$
- TVC (log_{10} cfu/cm^2)	2.64 (0.901)	2.73 (1.163)	ns
- Coliforms (cfu/cm^2)	1.3 (3.87)	3.8 (7.27)	$p<0.001$
- *E.coli* (cfu/cm^2)	0.6 (2.13)	1.8 (4.86)	$p<0.01$

3.3 OVINES

3.3.1 Procedure score

Figure 11 shows that only two establishments improved their average procedure score over the 18-month period of this study. Figure 12 provides an examination of procedure score by workstation. Worse procedure scores have been recorded for sticking, weasand rod and tie, opening and clearing the brisket and flank, clearing foreleg and neck, bunging and removal of the gut and pluck.

FIGURE 11: OVINE PROCEDURE SCORE BY ESTABLISHMENT OVER TIME
(Lower scores indicate best procedures)

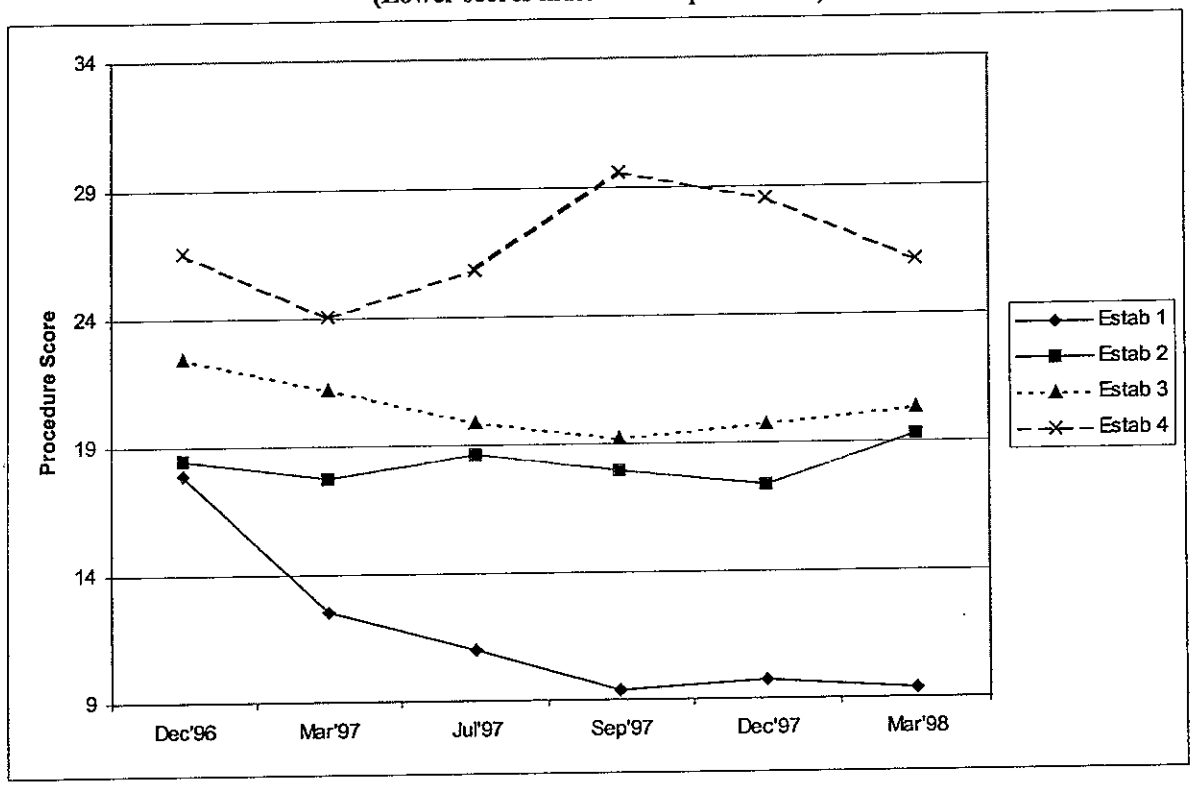


Figure 13 provides an examination of procedure score by procedure type for all workstations. The procedures recording worse scores include: unwashed hands, incorrect knife sanitisation; cutting down rather than using a spear cut; roll-in of pelt; and opportunity for internal contents leakage.

As discussed in section 3.3.3.4, procedure scores in ovine processing establishments were associated with both carcase macro- and micro-contamination. However, the correlation between procedure score and micro-contamination of ovine carcases in this study was small ($R=0.46$, $p<0.01$). A slightly higher correlation was recorded between procedure score and macro-contamination levels prior to trimming and washing ($R=0.86$, $p<0.001$). After trimming and washing a smaller correlation between procedure score and macro-contamination was recorded ($R=0.41$, $p<0.01$). This suggests processors have corrective action in place to reduce the contamination on ovine carcases.

FIGURE 12: PROCEDURE SCORE BY WORKSTATION – OVINE
(Lower scores indicate best procedures)

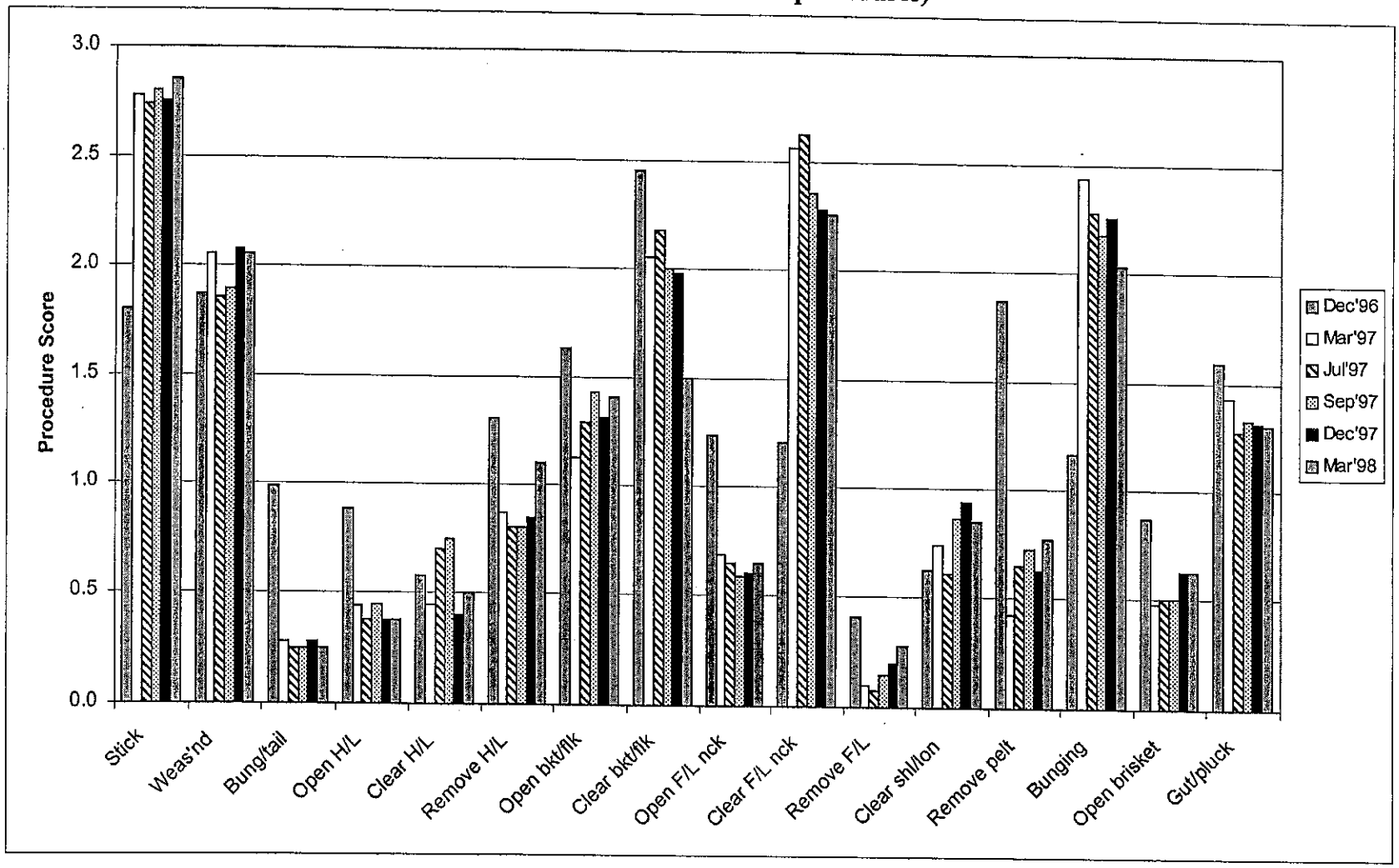
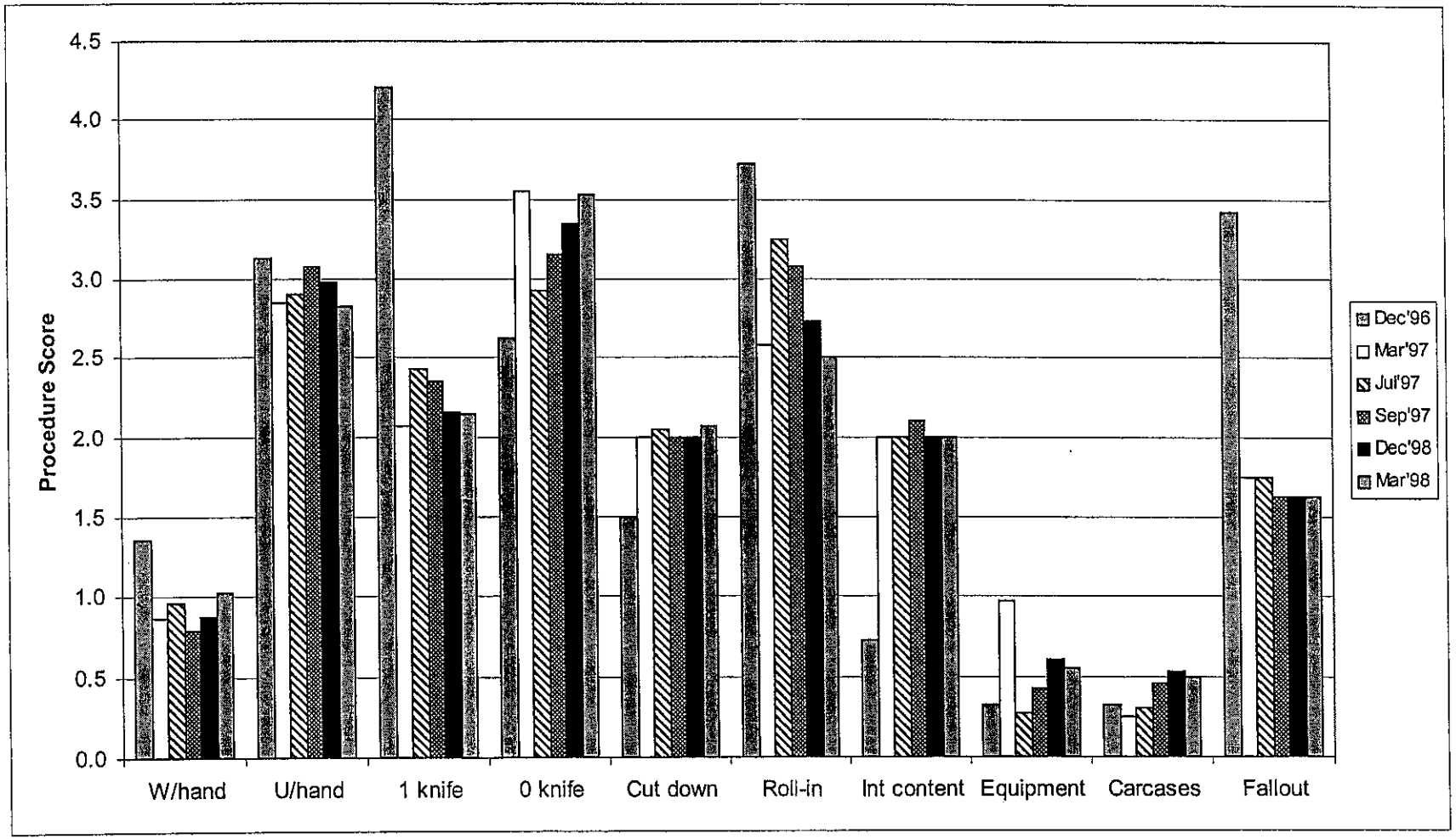


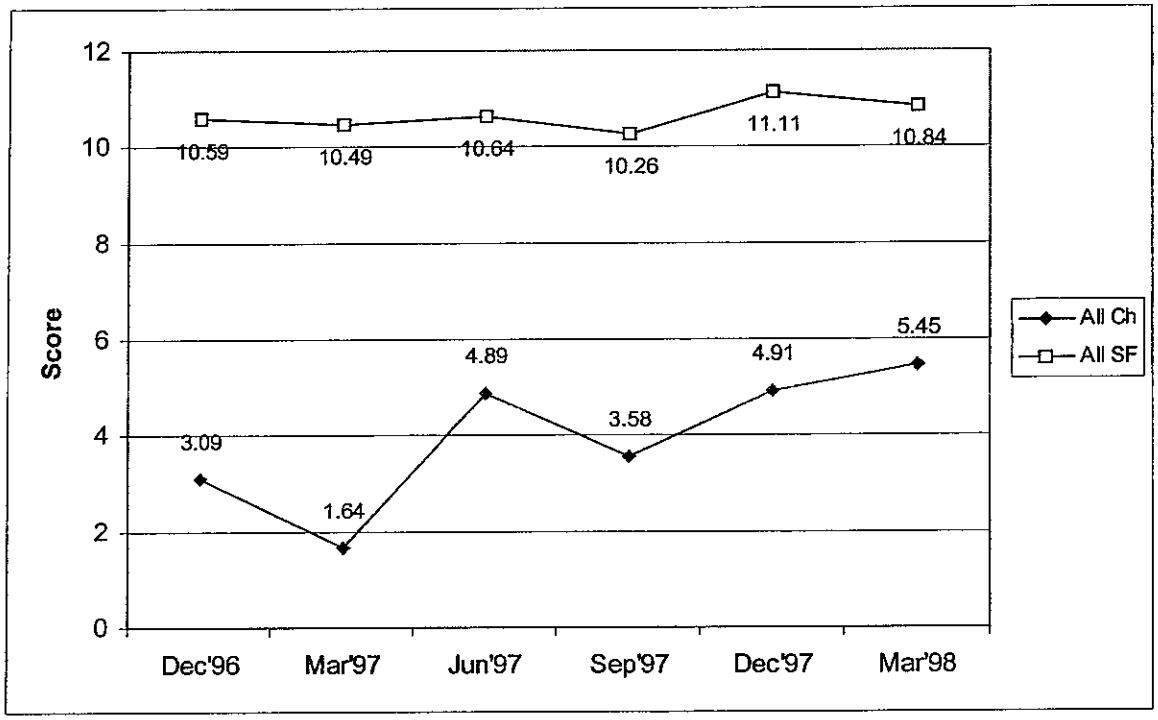
FIGURE 13: PROCEDURE SCORE BY PROCEDURE TYPE – OVINE
(Lower scores indicate best procedures)



3.3.2 Macro-contamination score

As shown in Figure 14, macro-contamination scores prior to trimming and washing (All SF) have generally remained constant from the first to last audits. On average, though, there has been a general upward trend in macro-contamination score after trimming and washing (All Ch).

FIGURE 14: OVINE MACROCONTAMINATION PRIOR TO (SLAUGHTERFLOOR) AND AFTER (CHILLER) TRIMMING AND WASHING (Lower scores indicate less macro-contamination)



Figures 15 and 16 show the macro-contamination scores of individual establishments prior to and after trimming and washing respectively. Although trends in macro-contamination scores have not followed trends in procedure score we did record small correlations between procedure score and macro-contamination score prior to ($R=0.86$, $p<0.001$) and after trimming and washing ($R=0.41$, $p<0.01$) of carcases. There were also small correlations between micro-contamination levels for carcases in the chiller and macro-contamination score prior to ($R=0.46$, $p<0.01$) and after trimming and washing ($R=0.36$, $p<0.05$). This is discussed further in section 3.2.3.4.

No establishment demonstrated improvement of macro-contamination scores after trimming and washing over the course of this study. We suggest that after trimming and washing, macro-contamination scores are at a level where little if any improvement can be demonstrated with the current system of corrective action (ie, trimming and washing). Although not recorded, the differences in scores between Estab 3/4 and Estab 1/2 in Figure 16

most likely reflect differences in the level of carcase trimming undertaken at each establishment (ie, higher levels of trimming at Estab 1 and 2).

FIGURE 15: ESTABLISHMENT MACRO-CONTAMINATION PRIOR TO TRIMMING AND WASHING - OVINE
(Lower scores indicate less macro-contamination)

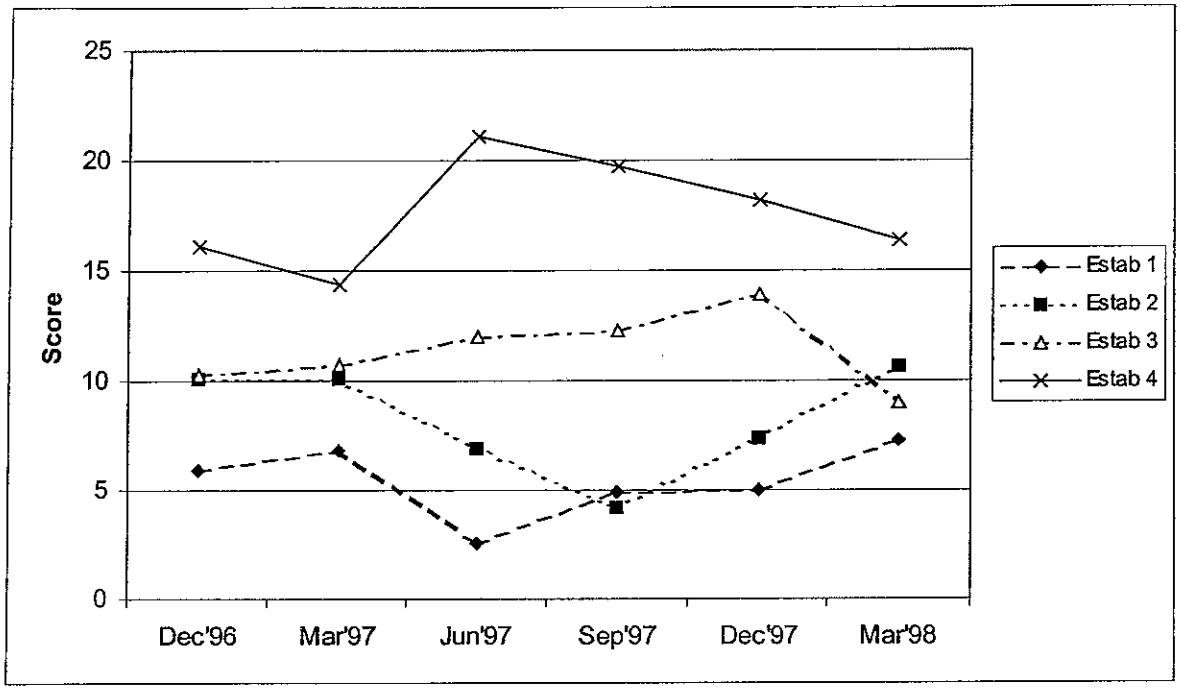
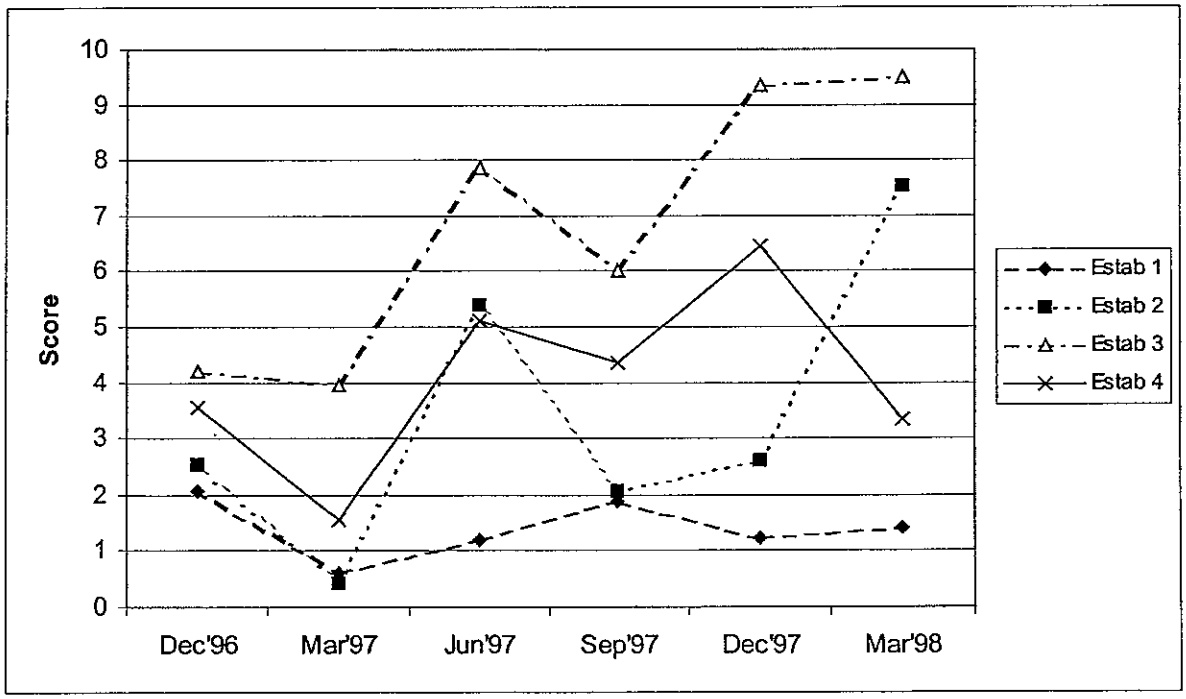


FIGURE 16: ESTABLISHMENT MACRO-CONTAMINATION AFTER TRIMMING AND WASHING - OVINE
(Lower scores indicate less macro-contamination)



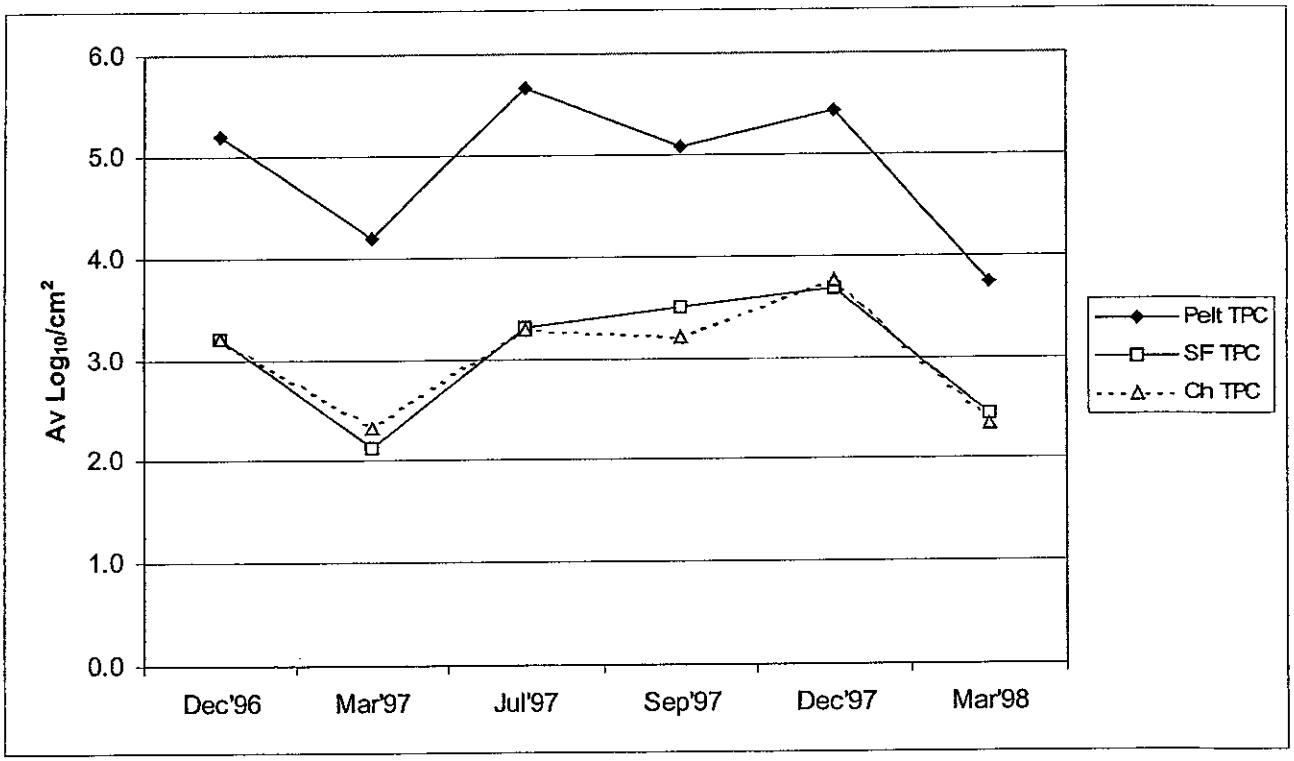
3.3.3 Microbial scores

3.3.3.1 Total aerobic plate count

Mean log aerobic plate counts for 'pelt on' (Hide TPC), 'prior to trim and wash' (SF TPC) and 'after trimming and washing' (CH TPC) are shown in Figure 17 for all establishments. The main findings were:

- The highest microbial loads were recorded from pelts (average 10^4 to 10^6 cfu* per cm^2) with carcase microbial counts below 10^4 cfu per cm^2
- Other than for December 1996, carcase microbial loads (SF TPC, Ch TPC) were highest during the winter and spring months. Over time, carcase microbial loads have reflected pelt microbial loads
- There has been no significant difference in microbial loads prior to (mean log=3.05, sd=1.124) or after trimming and washing (mean log=3.03, sd=0.969)
- Other than for Dec'96, ovine carcase microbial loads have followed the same trend as recorded for cattle over time (cf Figure 7).

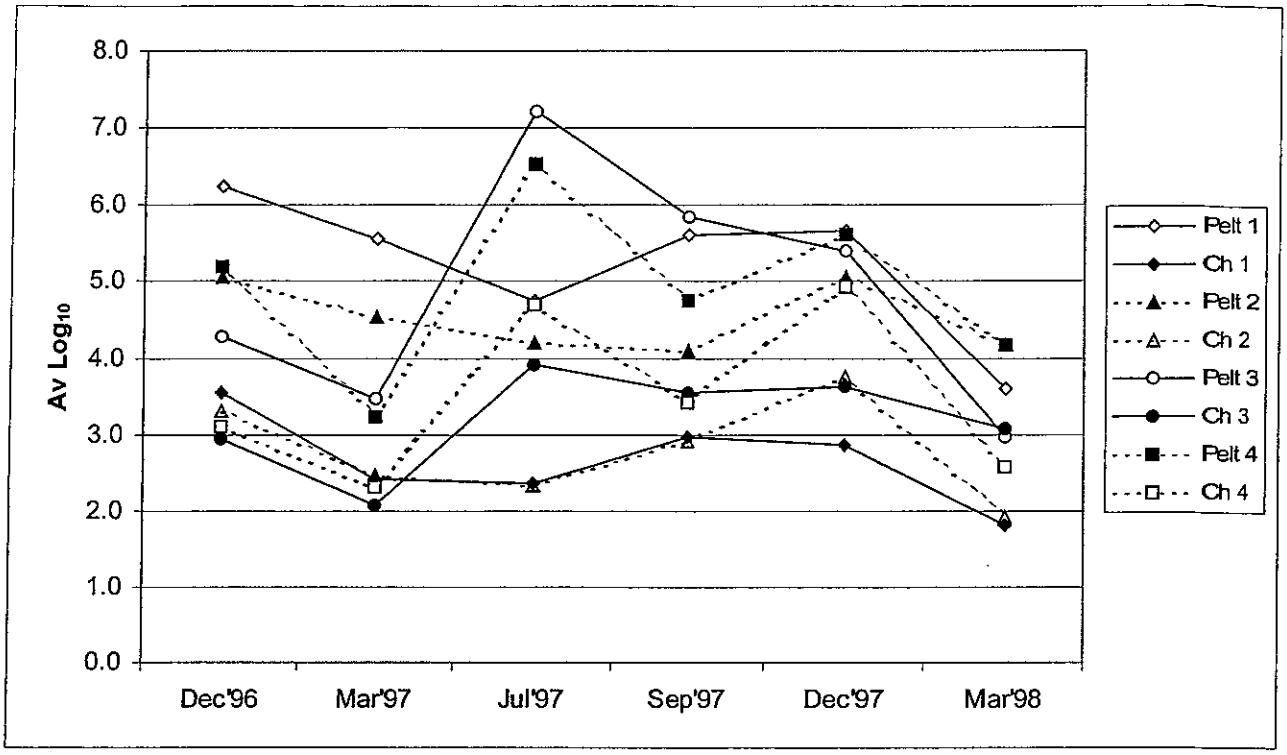
FIGURE 17: TOTAL AEROBIC PLATE COUNTS (GEOMETRIC MEAN)



Microbial loads by establishment are shown in Figure 18. In general, carcase microbial loads at each establishment have reflected pelt microbial loads.

* cfu – Colony forming unit

FIGURE 18: TOTAL AEROBIC PLATE COUNTS BY ESTABLISHMENT



Regression analysis confirms carcase microbial loads are primarily related to pelt microbial loads of animals slaughtered. Factors that may contribute to carcase microbial loads are shown in Table 6. Because most lots were mixed sex and not mulesed, no comparison has been possible between males and females or mulesed and not mulesed. Ovines scored with dirty/dusty pelts showed no difference in carcase microbial contamination than those scored with clean pelts. A small sample size for animals scored with wet pelts prevented any comparison being made between wet and dry pelts.

With respect to the results presented in Table 6:

- One establishment routinely crutched carcases on the chain that may have influenced the results presented for all data in the crutched v non-crutched comparison. Indeed in a small trial we undertook at this establishment, it would appear there is no difference in microbial counts of carcases that have been crutched. However, if the starting pelt microbial counts were taken into account, there may have been a benefit from crutching.
- Four ranges for wool lengths were used in this study namely 0-1, 1-5, 5-10 and 10+cm but differences in microbial counts were only observed below and above 5cm.
- The lower incidence of microbial counts for animals with pelts scored as seedy may be a result of the greater level of trimming likely to have occurred for seedy carcases (ie, every endeavour made to remove grass seeds embedded in the carcase).

TABLE 6: FACTORS INFLUENCING OVINE CARCASE MICROBIAL CONTAMINATION

Factor	No.	Mean log TVC (sd)		
		Pelt	Carcase	
			Pre-trim/Wash	Post-trim/Wash
Wool Length				
- 0-5cm	160	4.59 (1.078)	2.65 (0.981)	2.78 (1.003)
- >5cm	320	5.03 (1.214)	3.25 (1.142)	3.16 (0.925)
		(p<0.001)	(p<0.001)	(p<0.001)
Crutched				
- No	260	4.75 (1.280)	2.87 (1.162)	2.92 (1.031)
- Yes	220	5.05 (1.046)	3.27 (1.044)	3.17 (0.867)
		(p<0.01)	(p<0.001)	(p<0.01)
On-site Trial				
- No	10	3.39 (0.919)	3.74 (1.381)	2.85 (0.882)
- Yes	10	4.94 (0.961)	3.04 (1.839)	2.27 (0.391)
		(p<0.01)	(ns)	(ns)
Seedy Pelt				
- No	380	4.98 (1.202)	3.19 (1.056)	3.18 (0.951)
- Yes	100	4.53 (1.059)	2.50 (1.215)	2.45 (0.798)
		(p<0.01)	(p<0.001)	(p<0.001)
Breed Type				
- Merino	40	5.01 (1.575)	3.70 (1.177)	3.97 (1.204)
- Crossbred	440	4.87 (1.147)	2.99 (1.104)	2.95 (0.896)
		(p<0.001)	(ns)	(p<0.05)
Dentition				
- 0 tooth	450	4.83 (1.166)	2.99 (1.095)	2.96 (0.898)
- 8 tooth	30	5.61 (1.277)	4.02 (1.174	4.07 (1.332)
		(p<0.01)	(p<0.001)	(p<0.001)
Purchase Type				
- Direct	140	4.75 (1.010)	2.92 (1.088)	2.71 (0.875)
- Saleyard	280	4.86 (1.198)	3.16 (1.180)	3.18 (1.001)
		(ns)	(p<0.05)	(p<0.001)
Travel Distance				
- 1-200 km	180	4.73 (1.109)	2.95 (0.940)	2.81 (0.737)
- 200+ km	300	4.98 (1.224)	3.11 (1.223)	3.17 (1.067)
		(p<0.05)	(ns)	(p<0.001)

3.3.3.2 Pelt Coliform/*E.coli* counts

Average carcase Coliform counts ranged from 14 cfu/cm^2 in March 1997 to 395 cfu/cm^2 in July 1997 (Figure 19). *E.coli* counts ranged from 5 cfu/cm^2 in March 1997 to 160 cfu/cm^2 in December 1997. These trends have not been in line with the TPC trend reported over the same period (see Figure 17).

3.3.3.3 Carcase Coliform/*E.coli* counts

As shown in Figure 20, average carcase Coliform counts have not exceeded 11 cfu/cm^2 (September 1997). Carcase *E.coli* counts have never exceeded an average of 9 cfu/cm^2 (December 1997).

FIGURE 19: AVERAGE PELT COLIFORM/*E.COLI* COUNTS OVER TIME

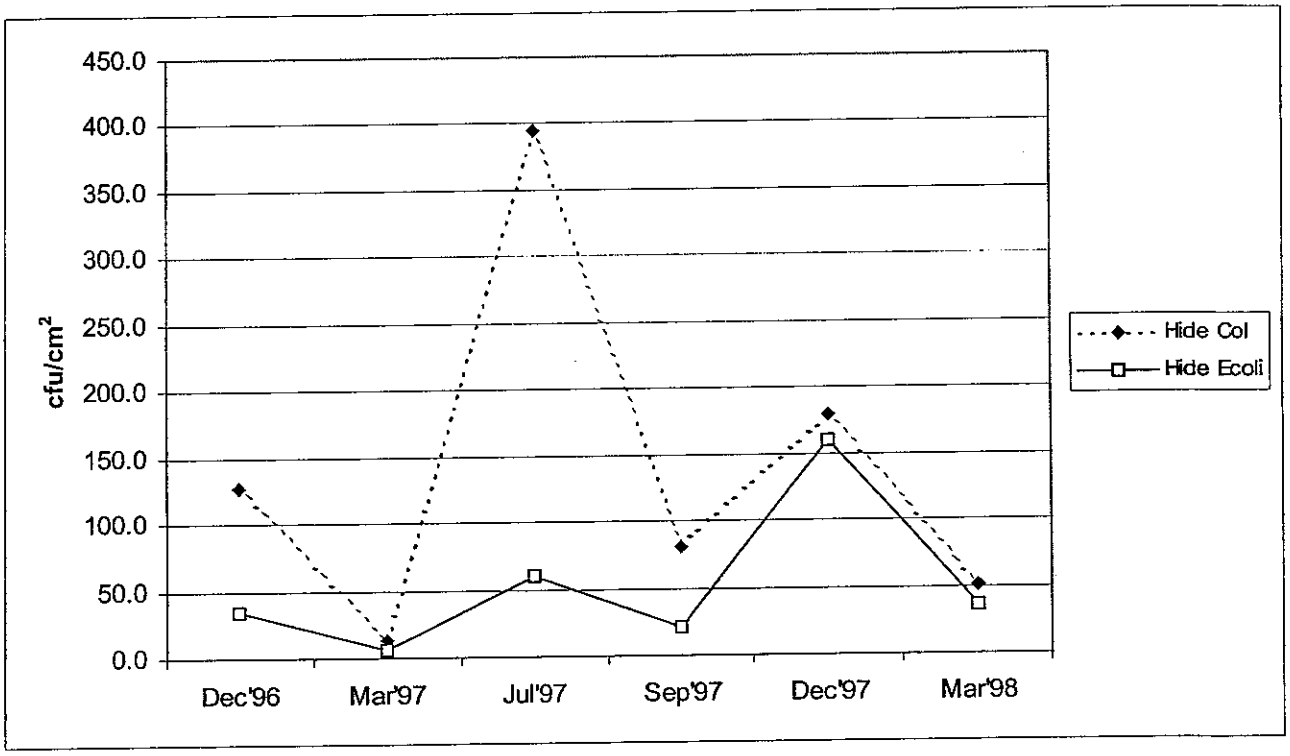
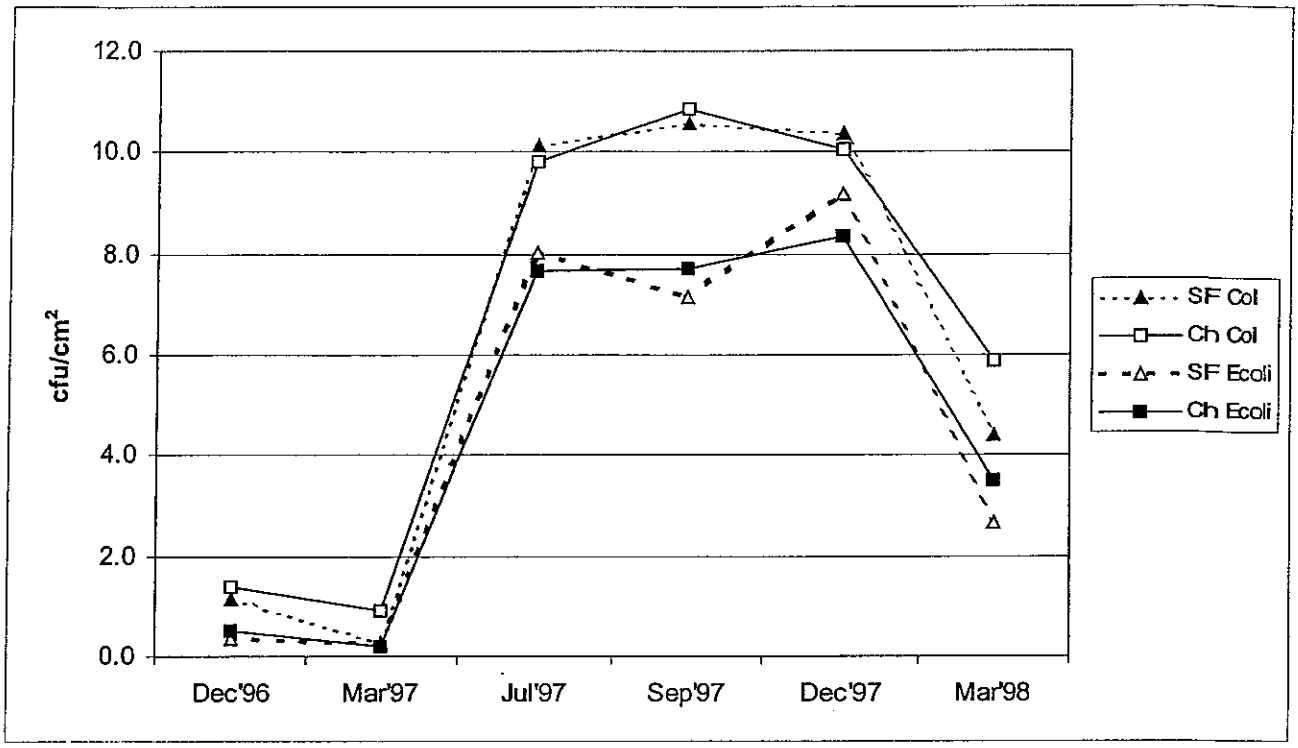


FIGURE 20: AVERAGE CARCASE COLIFORM/*E.COLI* COUNTS PRIOR TO (SF) AND AFTER (CH) TRIMMING AND WASHING



Regression analysis showed carcase Coliform and *E.coli* contaminations were primarily related to:

- Procedure score – higher the score, greater the contamination
- Maximum temperature – lower the temperature, greater the contamination
- Pelt microbial loads – higher the load, greater the contamination
- Pelt length – longer the wool, greater the contamination

A comparison of other factors that may contribute to carcase Coliform and *E.coli* loads are shown in Tables 7 and 8 respectively. Because most lots were mixed sex and not mulesed, no comparison has been possible between males and females or mulesed and not mulesed. Ovines scored with dirty/dusty pelts had no more carcase microbial contamination than those scored with clean pelts. A small sample size for animals scored with wet pelts has prevented any comparison being made between wet and dry pelts.

With respect to the results presented in Tables 7 and 8:

- No breed differences were recorded for Coliform and *E.coli* counts and so this data has not been included
- Despite Table 6 possibly indicating increased total microbial counts on carcases that had been crutched, Tables 7 and 8 show lower Coliforms and *E.coli* counts respectively.
- Four ranges for wool lengths were used in this study namely 0-1, 1-5, 5-10 and 10+cm but differences in microbial counts were only observed below and above 5cm.
- The lower incidence of Coliform and *E.coli* counts for animals with pelts scored as seedy may be a result of the greater level of trimming likely to have occurred for seedy carcases.

TABLE 7: FACTORS INFLUENCING OVINE CARCASE COLIFORM CONTAMINATION

Factor	No.	Mean Coliform count cfu/cm^2 (sd)		
		Pelt	Carcase	
			Pre-trim/Wash	Post-trim/Wash
Wool Length				
- 0-5cm	160	169 (632.9)	3.6 (6.87)	3.9 (7.00)
- >5cm	320	127 (465.9)	7.4 (8.34)	7.8 (8.60)
		(ns)	(p<0.001)	(p<0.001)
Crutched				
- No	260	145 (562.6)	6.7 (8.31)	7.4 (8.52)
- Yes	220	137 (483.1)	5.5 (7.80)	5.4 (7.91)
		(ns)	(ns)	(p<0.01)
Seedy Pelt				
- No	380	157 (567.2)	6.9 (8.42)	7.3 (8.59)
- Yes	100	81 (329.1)	3.4 (6.01)	3.4 (6.21)
		(ns)	(p<0.001)	(p<0.001)
Dentition				
- 0 tooth	450	103 (419.3)	5.8 (7.88)	6.4 (8.23)
- 8 tooth	30	713 (1227.6)	11.6 (9.52)	8.0 (8.62)
		(p<0.05)	(p<0.01)	(ns)
Purchase Type				
- Direct	140	111 (433.6)	4.1 (6.15)	4.3 (6.76)
- Saleyard	280	182 (614.2)	7.2 (8.72)	7.3 (8.63)
		(ns)	(p<0.001)	(p<0.001)
Travel Distance				
- 1-200 km	180	145 (536.7)	4.9 (7.37)	5.6 (7.82)
- 200+ km	300	138 (522.2)	6.9 (8.42))	7.0 (8.54)
		(ns)	(p<0.01)	(ns)

TABLE 8: FACTORS INFLUENCING OVINE CARCASE *E.COLI* CONTAMINATION

Factor	No.	Mean *E.coli* count cfu/cm^2 (sd)		
		Pelt	Carcase	
			Pre-trim/Wash	Post-trim/Wash
Wool Length				
- 0-5cm	160	37 (162.6)	2.6 (5.97)	3.2 (6.46)
- >5cm	320	61 (292.0)	5.6 (7.96)	5.4 (7.86)
		(ns)	(p<0.001)	(p<0.01)
Crutched				
- No	260	59 (287.2)	4.9 (7.57)	5.5 (7.90)
- Yes	220	45 (214.6)	4.1 (7.37)	3.6 (6.86)
		(ns)	(ns)	(p<0.01)
Seedy Pelt				
- No	380	50 (240.7)	5.3 (7.98)	5.3 (7.87)
- Yes	100	62 (309.7)	1.9 (4.29)	2.3 (5.28)
		(ns)	(p<0.001)	(p<0.001)
Dentition				
- 0 tooth	450	46 (247.3)	4.2 (7.22))	4.5 (7.39)
- 8 tooth	30	151 (356.6)	10.0 (9.35	7.4 (8.59)
		(ns)	(p<0.01)	(ns)
Purchase Type				
- Direct	140	4.75 (1.010)	2.92 (1.088)	2.71 (0.875)
- Saleyard	280	4.86 (1.198)	3.16 (1.180)	3.18 (1.001)
		(ns)	(p<0.05)	(p<0.001)
Travel Distance				
- 1-200 km	180	4.73 (1.109)	2.95 (0.940)	2.81 (0.737)
- 200+ km	300	4.98 (1.224)	3.11 (1.223)	3.17 (1.067)
		(p<0.05)	(ns)	(p<0.001)

3.3.3.4 Relationship between Procedure Score, Macro- and Micro-Contamination on Ovine Carcases

Tables 9 to 11 provide comparisons between procedure score, macro-contamination scores and total micro-contamination levels of ovine carcases in this study. To compare the macro-contamination scores with AQIS Meat Hygiene Assessments, the following should be used as a guide:

Alliance Score	AQIS MHA
0	No observable contamination
1	Minor defect
2	Major defect
3	Critical defect

Alliance scores were cumulative across macro-contamination type and area on the carcase. Therefore individual carcase scores could exceed '3' depending on the level of macro-contamination over the carcase (see section 2).

TABLE 9: COMPARISON BETWEEN TOTAL MICROBIAL CONTAMINATION AND MACRO-CONTAMINATION AND PROCEDURE SCORES FOR OVINE CARCASES

Factor	No.	Mean log TVC (sd)		
		Hide	Carcase	
			Pre-trim/Wash	Post-trim/Wash
Procedure Score				
- 0-12	80	4.90 (1.101)^{ab}	2.55 (0.939)^{a}	2.49 (0.728)^{a}
- 12.1-18	100	5.10 (0.844)^{a}	2.71 (0.829)^{a}	3.01 (0.833)^{b}
- 18.1-21	140	4.98 (1.375)^{a}	3.26 (1.179)^{b}	3.10 (0.880)^{bc}
- 21.1+	160	4.65 (1.207)^{b}	3.34 (1.191)^{b}	3.26 (1.117)^{c}
Pre-trim/wash Macro Score				
- 0-5	95	5.07 (0.944)^{a}	2.82 (0.698)^{ab}	2.88 (0.771)^{a}
- 6-10	164	4.59 (1.210)^{b}	2.75 (1.075)^{b}	2.76 (0.837)^{a}
- 11-15	118	4.75 (1.203)^{b}	3.03 (1.185)^{a}	2.96 (0.952)^{a}
- 16+	103	5.34 (1.188)^{a}	3.78 (1.147)^{c}	3.69 (1.047)^{b}
Post-trim/wash Macro Score				
- 0-1	133	4.81 (0.984)	2.53 (0.933)^{a}	2.73 (0.767)^{a}
- 2-3	131	4.78 (1.117)	2.96 (1.010)^{b}	2.93 (0.890)^{a}
- 4-6	118	5.00 (1.154)	3.42 (1.168)^{c}	3.25 (1.049)^{b}
- 7+	98	4.99 (1.521)	3.42 (1.171)^{c}	3.33 (1.069)^{b}

a,b,c – Within a cell, means with differing subscripts differ significantly ($p<0.05$)

TABLE 10: COMPARISON BETWEEN COLIFORM CONTAMINATION AND MACRO-CONTAMINATION AND PROCEDURE SCORES FOR OVINE CARCASES

Factor	No.	Mean Coliform count cfu/cm^2 (sd) Hide	Carcase Pre-trim/Wash	Carcase Post-trim/Wash
Procedure Score				
- 0-12	80	275 (734.8)^a	4.2 (6.86)^a	2.5 (5.35)^a
- 12.1-18	100	75 (290.4)^b	3.3 (6.22)^a	5.9 (8.29)^b
- 18.1-21	140	95 (416.5)^b	7.6 (8.17)^b	8.7 (8.54)^c
- 21.1+	160	156 (592.3)^{ab}	7.8 (8.96)^b	6.9 (8.60)^{bc}
Pre-trim/wash Macro Score				
- 0-5	95	235 (664.5)^{ac}	5.4 (7.45)^a	5.0 (7.47)^a
- 6-10	164	31 (104.0)^{bc}	4.1 (6.83)^a	5.3 (7.60)^a
- 11-15	118	130 (534.2)^c	5.5 (7.67)^a	5.8 (8.13)^a
- 16+	103	243 (717.6)^{ac}	11.1 (9.08)^b	10.5 (9.11)^b
Post-trim/wash Macro Score				
- 0-1	133	144 (516.6)	2.7 (5.84)^a	3.1 (6.29)^a
- 2-3	131	117 (457.7)	5.5 (7.76)^b	5.5 (8.03)^b
- 4-6	118	178 (632.1)	8.1 (8.69)^c	8.14 (8.65)^c
- 7+	98	124 (493.6)	9.2 (8.61)^c	10.4 (8.61)^d

a,b,c – Within a cell, means with differing subscripts differ significantly ($p<0.05$)

TABLE 11: COMPARISON BETWEEN *E.COLI* CONTAMINATION AND MACRO-CONTAMINATION AND PROCEDURE SCORES FOR OVINE CARCASES

Factor	No.	Mean *E.coli* count cfu/cm^2 (sd) Hide	Carcase Pre-trim/Wash	Carcase Post-trim/Wash
Procedure Score				
- 0-12	80	71 (343.9)	3.2 (6.37)^{ab}	1.8 (4.28)^a
- 12.1-18	100	25 (61.3)	2.2 (5.20)^b	4.6 (7.54)^b
- 18.1-21	140	71 (349.2)	5.1 (7.42)^{ac}	5.3 (7.73)^b
- 21.1+	160	45 (170.7)	6.3 (8.72)^c	5.6 (8.18)^b
Pre-trim/wash Macro Score				
- 0-5	95	65 (319.2)^{ab}	3.3 (6.33)^a	3.9 (6.74)^a
- 6-10	164	17 (38.1)^a	2.6 (5.48)^a	3.4 (6.32)^a
- 11-15	118	51 (282.5))^{ab}	4.0 (7.09)^b	3.9 (7.18)^a
- 16+	103	99 (341.1)^b	9.6 (9.32)^b	8.3 (9.02)^b

Factor	No.	Mean *E.coli* count cfu/cm^2 (sd)		
		Hide	Carcase	
			Pre-trim/Wash	Post-trim/Wash
Post-trim/wash Macro Score				
- 0-1	133	24 (71.6)^{a}	2.1 (5.30)^{a}	2.1 (5.20)^{a}
- 2-3	131	55 (272.6)^{ab}	3.8 (6.91)^{a}	4.2 (7.28)^{b}
- 4-6	118	48 (281.6))^{ab}	5.9 (8.32)^{b}	5.9 (8.12)^{bc}
- 7+	98	95 (345.2)^{b}	7.2 (8.48)^{b}	7.3 (8.46)^{c}

a,b,c – Within a cell, means with differing subscripts differ significantly ($p<0.05$)

It appears from Tables 9-11 that a procedure score in excess of 12 was required before any difference in carcase microbial contamination was detected. Macro contamination scores needed to exceed an average carcase score of '15' pre-trim and wash and score '2-3' post trim and wash before any detrimental effect on carcase microbial contamination was observed. This equates to every carcase scoring at least one critical defect under the AQIS or ARMCANZ Meat Hygiene Assessment systems and is therefore far greater than currently allowed under these systems.

Based on our findings presented in Tables 9-11 we would propose that the AQIS or ARMCANZ Meat Hygiene systems may be operating in too narrow a range for changes in macro-contamination to have any real effect on micro-contamination of ovine carcases. It would therefore appear unnecessary to undertake extensive daily monitoring if an establishment could demonstrate it was operating below certain standards. With respect to the Alliance scoring system used in this study, this would apply to those establishments demonstrating procedure scores below 12, pre-trim macro-contamination scores below 15 and post-trim macro-contamination scores below 3. Reduced levels of monitoring would then be acceptable. Of course, suitable recognition would need to be made of overseas country requirements (eg, zero tolerance in the USA) although a scientific argument could be mounted to counter what appears to be a non-productive activity based on the results presented here.

3.3.3.5 Ovine Establishment Type

Table 12 provides the average procedure score, macro-contamination score and carcase microbial loads recorded in Export and Domestic licensed ovine processing establishments in this study. On average, domestic establishments recorded higher procedure scores, macro-contamination scores and carcase microbial counts.

TABLE 12 : RELATIONSHIP BETWEEN OVINE PROCESSING ESTABLISHMENT TYPE, PROCEDURE, MACRO- AND MICRO-CONTAMINATION SCORES

Score Mean (sd)	Export License (n=240)	Domestic License (n=240)	Significance Level
Procedure Score	14.9 (3.96)	23.6 (3.51)	p<0.001
Hide Microbial Load			
- TVC (log_{10} cfu/cm^2)	4.88 (0.926)	4.89 (1.402)	ns
- Coliforms (cfu/cm^2)	139 (504.7)	143 (549.7)	ns
- *E.coli* (cfu/cm^2)	40 (206.7)	66 (297.6)	ns
Pre-trim/Wash			
- Macro-contamination score	6.8 (3.50)	14.5 (4.82)	p<0.001
- TVC (log_{10} cfu/cm^2)	2.62 (0.833)	3.50 (1.210)	p<0.001
- Coliforms (cfu/cm^2)	3.8 (6.57)	8.6 (8.77)	p<0.001
- *E.coli* (cfu/cm^2)	2.3 (5.28)	6.8 (8.63)	p<0.001
Post-trim/Wash Microbial Load			
- Macro-contamination score	2.4 (2.59)	5.4 (3.52)	p<0.001
- TVC (log_{10} cfu/cm^2)	2.72 (0.822)	3.35 (0.998)	p<0.001
- Coliforms (cfu/cm^2)	4.2 (7.02)	8.8 (8.83)	p<0.001
- *E.coli* (cfu/cm^2)	2.9 (5.93)	6.4 (8.44)	p<0.001

3.3.4 Ovine Observations

The following observations are based on the data obtained from this study:

1. Microbial loads on the pelts of carcases being processed had the strongest association with final carcase microbial counts. However, final carcase Coliform and *E.coli* contaminations were also associated with procedure score, pelt length and maximum daily temperature (ie, higher counts during winter and spring)
2. Improving procedure score within an establishment has not led to improved macro or micro-contamination scores. Higher procedure scores between establishments have, however, been associated with worse macro-contamination scores and worse micro-contamination scores. This finding suggests major changes to procedures are required to reduce overall carcase contamination
3. Delivery of short wool animals that have been crutched is likely to lower micro-contamination levels and reduce the need for trimming
4. Compared to domestic establishments, export establishments recorded better procedures, lower macro-contamination levels and lower carcase microbial contamination
5. In export establishments carcase microbial levels appear to be higher after corrective action (ie, after trimming and washing; average increase 0.10 log_{10} for export and –0.15 log_{10} for domestic). This may be due to cross contamination from increased handling of carcases in export establishments during corrective action

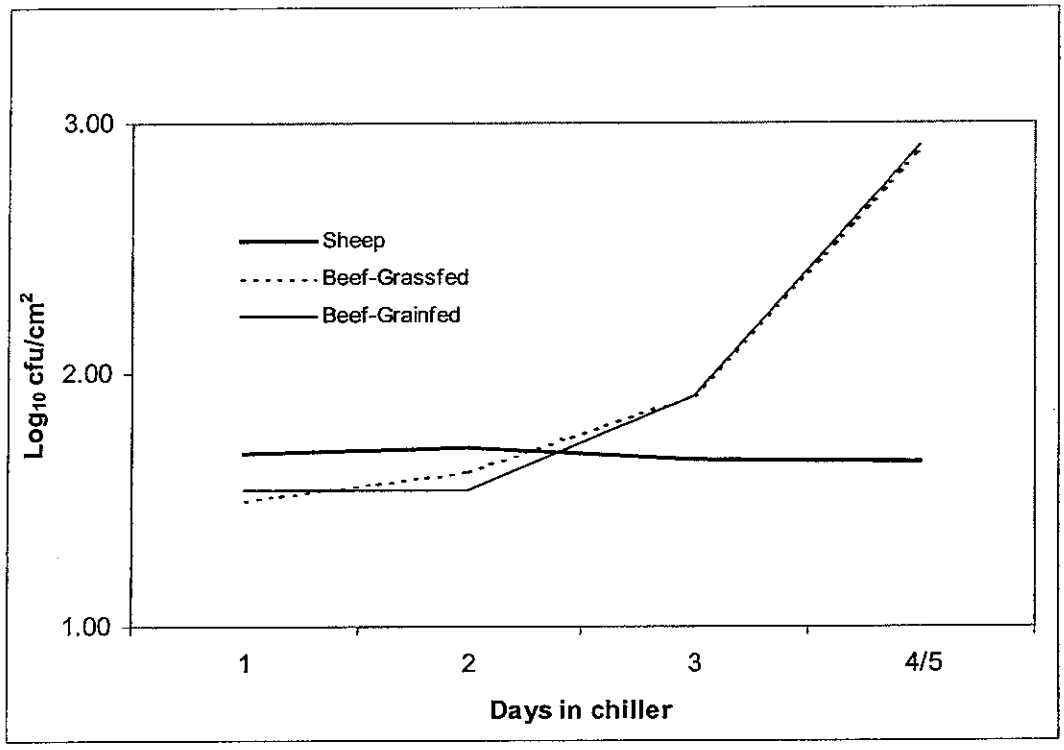
6. Carcases from animals transported less than 200km tend to have lower pelt and carcase microbial counts than those travelling longer distances
7. Carcases from animals purchased out of saleyards tend to have higher pelt and carcase microbial counts than those purchased direct-to-works.

3.4 ANALYSIS OF SITE DATA

3.4.1 Chilling time

Figure 21 shows that microbial counts increased for bovine carcases (n=473) with increasing time in the chillers but not for ovine carcases (n=628). For bovine carcases there has been no difference between grain and grass fed carcases over time in the chiller.

FIGURE 21: MICROBIAL (TVC) SCORES FOR BOVINE AND OVINE CARCASES AFTER DIFFERING CHILL TIMES



3.4.2 Carcase sites

Table 13 provides a ranking of the level of micro-contamination by bovine carcase site for this study (MRC), data received from an individual establishment in the study (Company) and a study undertaken in Switzerland (Untermann *et al*, 1997).

Bovine carcase sites consistently recording higher than average microbial counts include the outside, foreshank and brisket. The topside site scored poorly in our study but better in the Swiss study while the shoulder site only scored poorly at the individual establishment.

The findings reported in Table 13 support the inclusion of both forequarter and hindquarter sites on the bovine carcase for verification of slaughter hygiene.

Table 14 provides a ranking of the level of micro-contamination by ovine carcase site for this study (MRC) and data received from an individual establishment in the study (Company). Ovine carcase sites consistently recording higher than average microbial scores include the flank, foreshank, brisket, rib and shoulder.

TABLE 13: RANKING OF MICROBIAL COUNTS (TVC) BY BOVINE CARCASE SITE

(Highest ranks indicates most contamination)

Carcase site	Rank		
	MRC	Company	Untermann
Outside	-	13	5
Foreshank	6	12	8
Brisket	8	11	7
Stifle	-	9.5	-
Shoulder	1	9.5	2
Stick	-	8	-
Topside	7	7	1
Hindshin	-	6	-
Neck	4	5	4
Flank	-	4	6
Rib	3	3	-
Channel	5	2	-
Loin	2	-	3
Tenderloin	-	1	-

TABLE 14: RANKING OF MICROBIAL COUNTS (TVC) BY OVINE CARCASE SITE

Carcase site	Rank (Highest ranks indicates most contamination)	
	MRC	Company
Flank	-	11
Brisket	6	10
Foreshank	5	9
Rib	8	8
Gut	-	6.5
Shoulder	7	6.5
Neck	2	5
Rump	4	4
Stifle	-	3
Loin	1	2
Hindshin	3	1

3.5 FURTHER RESEARCH

This study has drawn attention to a number of issues that warrant further investigation. These include:

1. The relative effect of carcase washing versus 'dry' dressing procedures on carcase microbial contamination. A positive outcome could lead to substantial cost reductions for meat processing establishments through water saving.
2. A closer investigation of some of the livestock factors which were not fully evaluated in this study, namely:
   - Grain versus grass feeding for bovines, particularly for long fed cattle
   - Broad breed type comparisons for ovines and bovines.
3. Establishment of a pathogen risk determination system for meat processing establishments based on a GIS model incorporating seasonal, geographical, spatial and livestock databases.

ANNEX 1

PROCEDURE SCORING SYSTEM

Procedure Scoring System

Correct Procedure	Score	Incorrect Procedure	Score
Wash hands after contamination	0	Touch edible tissue after contamination	0.5
Wash hands between carcases	0	Unwashed hands	0.5
2 Knife sanitisation	0	1 Knife sanitisation	0.5
Correct utensil sanitisation	0	Incorrect utensil sanitisation	0.5
Hide/Wool does not roll in	0	Hide/Wool roll in	1
Correct equipment sanitisation	0	Incorrect equipment sanitisation	1
No internal contents leakage	0	Internal contents leakage	1
No construction contact with carcase	0	Construction contact	1
No carcase contact	0	Carcase contact	1

ANNEX 2

MACRO-CONTAMINATION SCORING SYSTEM

Macro-contamination Scoring System

Macro-contaminate	Beef Side	Sheep Carcase
Hair/Wool	0 - None 1 - 1-10 fibres or 1 cluster 2 - 10-30 fibres or 2-3 clusters 3 - >30 fibres or >3 clusters	
Hide/Skin	0 - None 1 - <1cm diameter 2 - 1-5cm diameter 3 - >5cm diameter	
Ingesta	0 - None 1 - <0.5cm diameter 2 - 0.5-1cm diameter 3 - >1cm diameter	
Faecal	0 - None 1 - <0.5cm diameter 2 - 0.5-1cm diameter or 1 pellet 3 - >1cm diameter or >1pellet	
Other - dust, dirt, grease, seed, etc	0 - None 1 - <1cm diameter or <10 specks 2 - 1-5cm diameter or 10-20 specks 3 - >5cm diameter or >20 specks	