SOURCES OF CONTAMINATION DURING SLAUGHTER AND MEASURES FOR CONTROL

J.J. SHERIDAN

Teagasc, The National Food Centre
Dunsinea, Castleknock, Dublin 15, Ireland

Received for Publication April 27, 1998
Accepted for Publication August 13, 1998

ABSTRACT

This paper is concerned with processes and procedures involved in the contamination of beef, lamb and pork carcasses during slaughter. The hides of beef and the fleece of sheep are major sources of carcass contamination. The spread of pathogens from beef hides to the carcass, operatives and surfaces in the abattoir is demonstrated. Efforts to clean the hide of cattle and the fleece of sheep are outlined, with reference to the success of these treatments in reducing carcass contamination. The effect of bringing very dirty or dungy animals to slaughter is considered in terms of the effect on carcass contamination after slaughter. The influence of tying the bung (or rectum) in reducing carcass contamination is discussed, as is the use of plastic bags as an additional control in preventing pathogen spread on pig carcasses. The relationship of this revised procedure in reducing the occurrence of yersiniosis in Norway is shown. The use of a commercially automated system to tie beef bungs is discussed in relation to reducing carcass contamination. A comparison between the removal of faecal contamination on carcasses by trimming or using a new steam-vacuumized system is presented. The effect of preevisceration washing of beef carcasses is described and the rationale relating to bacterial removal using this treatment is discussed. The influence of evisceration as a source of carcass contamination is demonstrated in relation to sheep slaughter. The processes of carcass decontamination using washing with water at different temperatures, steam pasteurization and hot lactic acid are compared in relation to their ability to remove bacteria from beef carcass surfaces. Finally, the effect of line speed and the impact of technology advances on beef and sheep carcass contamination is reviewed.

INTRODUCTION

Most sectors of the food industry face a major and continuing challenge in trying to limit the extent to which food products become contaminated with pathogenic bacteria during primary processing. Nowhere is this more apparent than in meat processing, where the production of meat from live animals presents many opportunities for contamination with a range of pathogens. In recent years the meat industry and regulatory authorities have attempted to limit the presence of pathogens on carcasses by the application of Hazard Analysis and Critical Control Points (HACCP) systems within meat plants. These are designed to assist in the management and control of the slaughter process by identifying the critical control points where contamination can occur and specifying actions that can be taken to improve the hygienic status of the carcass.

This paper considers the different points on the line where intervention can affect carcass hygiene and examines the impact of new process efficiency or safety technologies on carcass hygiene. While carcass decontamination is important in this context and is considered here, it is not considered in a comprehensive way. It also assesses the long-term effects of the gradual introduction of new technology and considers the impact of other process variables, such as line speed, on carcass hygiene.

Pathogen Control on the Live Animal

In any HACCP program for the primary processing of meat the state of the live animal is a major critical control point. The physiological state of the animal and internal and external microbial loading are all important determinants of the final microbiological quality of derived meats. Among these factors, the presence of faeces on animal hides, fleece or skin has long been recognized as a major source of pathogens on carcasses (Roberts 1980). This is not to suggest that other factors such as plant design, slaughter procedures and adherence to good manufacturing practices, are not also important in ensuring the production of carcasses of good hygienic quality. According to a generic HACCP for raw beef of the National Advisory Committee on Microbiological Criteria for Food, preslaughter washing has a positive effect in removing soil from animals (Anon. 1993). While some countries, such as New Zealand, have accepted the value of this process, and adopted a national policy of presenting washed animals for slaughter, the efficacy of this procedure has frequently been challenged (Roberts 1980; Biss and Hathaway 1995; Bell 1997). In spite of these reservations many agencies are targeting the hide as a major control point for the control of meat hygiene and insisting on clean animals being presented for slaughter (Ridell and Korkeala 1993; Anon. 1995; Anon. 1997; Lowman *et al.* 1997).

There is little doubt that pathogens such as *Escherichia coli* O157:H7 are spread from the hide to the carcass during slaughter. This is shown in Table 1, where prior to slaughter, live cattle were inoculated on the flank and rump, over a combined area of about 800 cm^2, with a mixture of faeces and the pathogen.

TABLE 1.
THE SPREAD OF *E. COLI* O157:H7 (log_{10}cfu/cm^2) FROM INOCULATED LIVE*
CATTLE HIDES TO CARCASS AND OTHER SURFACES AFTER SLAUGHTER

Carcass	Carcass Location		Surfaces: Operatives Hands	Saws	Knives	Flares+
Left side	Hind	2.82	3.68	2.81	1.92	-0.33
	Fore	-0.38				
Right side	Hind	2.86				
	Fore	1.53				

* Live animals (n = 10)
\+ Rotating blades used to trim and dehide beef carcasses
Mean inoculum level on hides -3.62 cfu/cm^2
Data: Bolton *et al.* (1997)

The resulting contamination of the carcass, the operatives and their implements, demonstrates the ease of spread of this pathogen during slaughter. This was particularly evident in terms of manual activities in that the numbers of the pathogen on the hands of the operatives were almost identical to the numbers inoculated onto the hide (Bolton *et al.* 1997). Although the animals were inoculated on the hindquarters only, both the fore and hindquarters of the carcass were subsequently contaminated. The hindquarters were most heavily contaminated and the appearance of the pathogen on the forequarter could have resulted from its redistribution during carcass washing with cold water.

The influence of excessive amounts of faecal contamination or dung on cattle, in relation to carcass contamination, is presented in Table 2. This shows that excessively dungy cattle yield carcasses with a higher level of contamination than normal animals (Ridell and Korkeala 1993).

TABLE 2.
EFFECT OF EXCESSIVE DUNG ON CATTLE HIDES ON CARCASS
TOTAL COUNTS (log_{10}cfu/cm^2)

Carcass Site	Control	Excessively Dungy
Shoulder	2.14^a	2.89^b
Brisket	3.82^c	4.50^d

Different superscripts within a row or column significantly different (P<.01)
Data: Ridell and Korkeala (1993)

The data in Table 3 shows that while the numbers of excessively dungy animals being presented at a meat plant were a small percentage of the total (2.17%), good farm management practices had significantly reduced the numbers over a period of seven years (Ridell and Korkeala 1993). Most of the dungy cattle were produced during the winter months and the factory adopted a policy for handling dungy cattle. Cleaner animals were slaughtered first while dungy cattle were retained and slaughtered separately at the end of the kill. During this period line speed is slower, so that greater care can be taken with these dirty animals and the added costs for this procedure are passed onto the farmer. It is interesting to note that even with greater care being taken the dungy animals still produced carcasses with higher counts (Table 2). Regulations similar to these in Finland for grading cattle for the amount of dung on the hide have been introduced into Irish export meat plants (Anon. 1997) and in the United Kingdom (Lowman *et al.* 1997).

TABLE 3.
NUMBER AND PERCENTAGE OF DUNGY CATTLE ARRIVING AT A SLAUGHTER HOUSE IN FINLAND

Year	Number Slaughtered	Excessively Dungy	
		No.	%
1983	76,840	1670	2.17
1986	63,970	604	0.94
1990	63,711	201	0.32

Data: Ridell and Korkeala (1993)

Recognition of the equivalent problem in sheep in controlling contamination of the fleece has resulted in shearing the fleece and then washing, or washing without shearing (Biss and Hathaway 1995). When animals with a long fleece (6 cm or more) were washed with cold water, significant increases in the levels of carcass contamination were observed (Table 4). These data suggest that washing the live animal does not enhance the microbial status of the carcass, even on shorn animals. While washing did not reduce the numbers of bacteria on carcasses, other contamination, such as faecal staining, can be significantly reduced (Biss and Hathaway 1995). At the present time equipment for dagging sheep and removing faecal clods from cattle hides are being developed at CSIRO in Australia (Stapleton 1997).

Finally, in relation to live animal decontamination, dehairing cattle or defleecing sheep has been attempted in the past (Schnell *et al.* 1995; Leach 1971). The data in Table 5 shows that these approaches have not been successful. Bacterial counts were not affected by either process, although the visual appearance of the meat was improved as a result of less hairs on the carcass and on the resulting meat. The removal of the fleece and hair in these studies was very different. For the fleece, the shedding agent (cyclophosphamide) was a drug, administered orally to the animals, while the cattle were dehaired with a chemical, sodium sulphide, applied topically. While oral defleecing avoided the pollution problems associated with dehairing, it had the disadvantage of being toxic in large doses (Dolnick *et al.* 1970). Although chemical dehairing of the live animal has not proved successful, it may be that, combined with other decontamination processes for carcasses, to be discussed below, it could have a future.

TABLE 4.
THE EFFECT OF PRE-SLAUGHTER STATUS ON LAMB CARCASS CONTAMINATION LEVELS ($log_{10}cfu/cm^2$) AFTER PELT REMOVAL

	Preslaughter Status			
	Clean Shorn	Dirty Shorn	Clean Woolly	Dirty Woolly
Washed	4.16	4.33	4.47	4.63
Unwashed	3.93	4.26	3.94	4.30
Effect of washing	N.S.	N.S.	$P<.001$	$P<.001$

Data: Biss and Hathaway, (1995)
NS = non significant

TABLE 5.
EFFECT OF CHEMICAL DEHAIRING OF BEEF OR DEFLEECING OF SHEEP ON MEAN BACTERIAL COUNTS ON CARCASSES

	Cattle ($log_{10}cfu/cm^2$)		
Treatment	Total Counts	Coliforms	*E. coli*
Dehaired	4.00a	1.96a	1.14a
Control	4.14a	1.64b	1.21a
Means in the same column followed by the same letter are not different ($P< .05$)			
	Sheep ($log_{10}cfu/carcass$)		
Defleeced	6.53	-	-
Control	7.18	-	-

Data: Beef - Schnell *et al.* (1995); Lamb - Leach (1971)

The Influence of "Bung Tying" on Pathogen Control

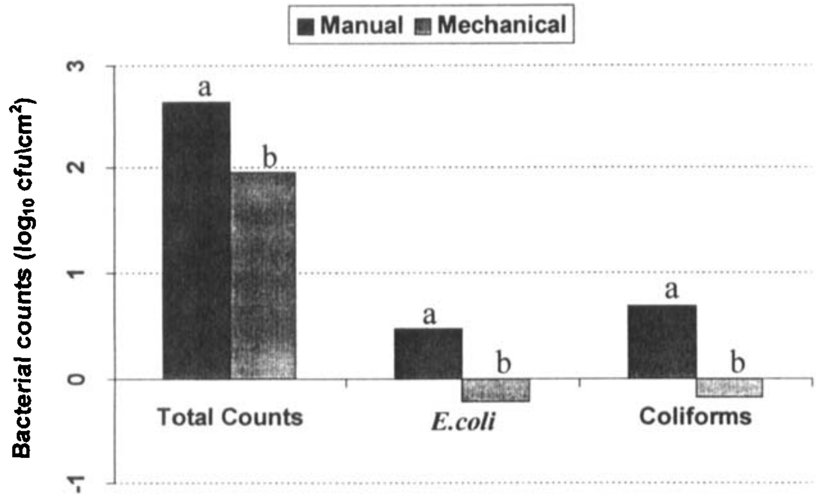
Tying the bung (rectum) or sealing the rectum of animals during slaughter is designed to reduce the spread of faecal material from the rectum to the carcass. In recent years this process has been improved by tying the bung and covering with a plastic bag. The effectiveness of this additional precaution in reducing contamination on pig carcasses has been demonstrated by Nesbakken *et al.* (1994). They showed that in commercial trials the occurrence of *Yersinia enterocolitica* 0:3 on pig carcasses was significantly reduced (Table 6). When this system was introduced into commercial production in Norway in 1994 the incidence of yersiniosis in the population decreased by 25% in the following year.

TABLE 6.
EFFECT OF A PLASTIC BAG TO SEAL THE RECTUM OF PIGS ON THE OCCURRENCE OF *YERSINIA ENTEROCOLITICA* 0:3 ON PIG CARCASSES DURING SLAUGHTER

	Country			
	Norway		Sweden	
Slaughter rate (no./h)	90.0		240.0	
Bung (1) covered with plastic bag (2) uncovered	(1)	(2)	(1)	(2)
Number of *Yersinia*-positive pigs	0	7(11.7)*	1.0(1.7)	5.0(8.3)*
Differences covered vs uncovered	P<.01			
Countries	N.S.			

*Percentage
NS = not significant
Data: Nesbakken *et al.* (1994)

A system to completely automate sealing the rectum of cattle has been developed in Australia and is presently commercially available (Leemon 1997). This 'safe seal' system has undergone commercial trials and has been shown to give significantly lower levels of carcass contamination, compared to the manual system (Fig. 1).



*AUSTRALIAN MEAT TECHNOLOGY SAFESEAL SYSTEM
Data: Leemon (1997)
[a,b] Means with different superscripts are significantly different ($P < 0.01$)

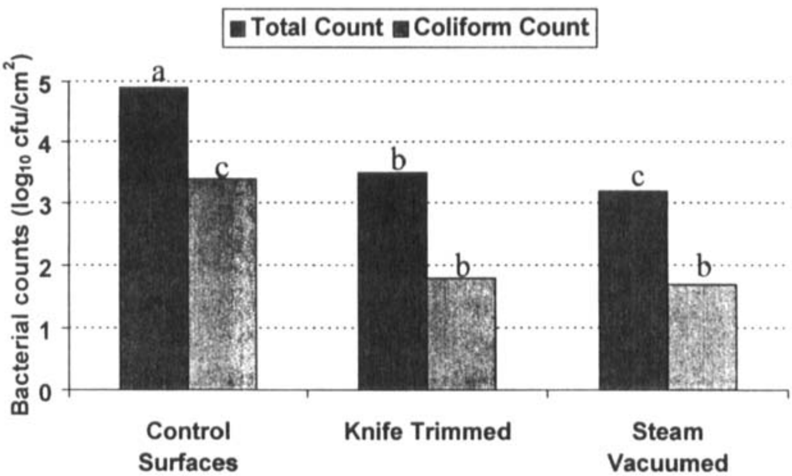
FIG. 1. COMPARISON BETWEEN A MANUAL AND A MECHANICAL SYSTEM TO SEAL THE BUNG OF CATTLE DURING SLAUGHTER

Trimming and Steam-Vacuuming

In order to comply with the zero tolerance criteria laid down by the US Food Safety Inspection Service (FSIS), carcasses must be free from all faecal staining prior to final washing (Anon. 1995). Trimming is an on-line process used to remove fat, small faecal spots and smears from beef carcasses. An alternative to trimming for the removal of small faecal stains is the use of steam-vacuuming. The processes of trimming and steam-vacuuming were applied to beef carcasses prior to evisceration and their ability to reduce bacterial numbers and faecal staining was assessed (Fig. 2). Steam-vacuuming was as successful in reducing bacterial numbers, including coliforms, as knife-trimming and both processes gave significant reductions compared to controls (Kochevar *et al.* 1997). Both treatments were also equally successful in removing visible faecal contamination. An added advantage of steam-vacuuming is the avoidance of producing contaminated waste meat.

Preevisceration Washing

Many HACCP systems recommend preevisceration washing or sanitizing immediately after dehiding as a means of reducing bacterial counts on the carcass at final dressing (Anon. 1993). It is carried out immediately after hide removal in order to obtain maximum effect in terms of bacterial removal. This is demonstrated in Fig. 3 which shows the added effectiveness of the preevisceration wash in reducing bacterial contamination after final washing. The basis of this improvement has been explained by Dickson (1995). If carcasses are washed soon after dehiding the ability of bacteria to adhere to the meat surface is reduced. This reduction results from a lowering of the meat surface tension which prevents bacterial adhesion.



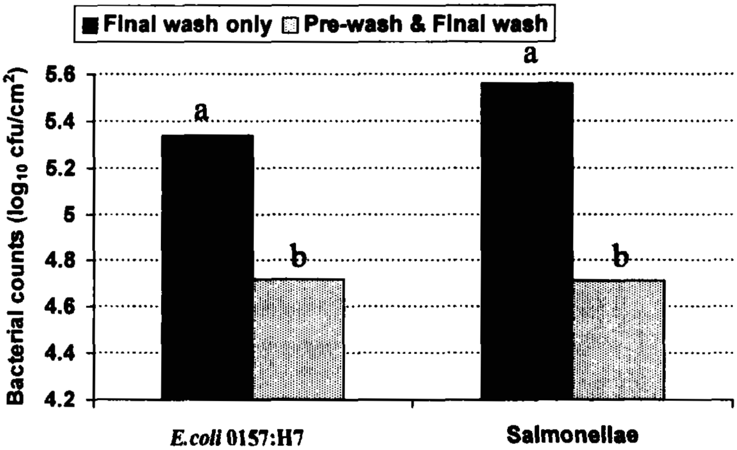
Data: Kochevar *et al.* (1997)

[abc] Means with different superscripts are significantly different ($P<0.05$)

FIG. 2. EFFECT OF STEAM VACUUMING OR KNIFE TRIMMING ON MEAN TOTAL AND COLIFORM COUNTS ($\log_{10}$ cfu/cm^2) ON BEEF CARCASSES SLAUGHTERED IN A COMMERCIAL ABATTOIR

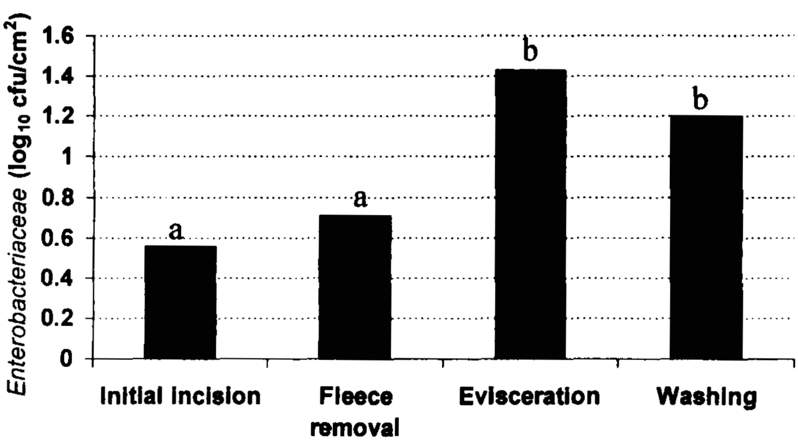
Evisceration

Evisceration may have an adverse effect on the contamination of meat. The influence of evisceration on the *Enterobacteriaceae* counts on lamb carcasses during slaughter is shown in Fig. 4. These data were the means from four different commercial plants in Ireland and show that contamination of the sternum/abdominal area of the carcass was significantly increased as a result of evisceration (Sierra *et al.* 1997). Increased *Enterobacteriaceae* counts after evisceration may have potential as an indicator of a deterioration in sheep slaughter practices.



Data: Dickson (1995)
[a,b] Means with different superscript letters are significantly different ($P<0.05$)

FIG. 3. EFFECT OF PRE-EVISCERATION WASHING ON BEEF CARCASSES INOCULATED WITH *E. COLI* O157:H7 OR SALMONELLAE



Data: Sierra *et al.* (1997)
[a,b] Means with different superscript letters are significantly different ($P<0.01$)

FIG. 4. THE INFLUENCE OF PROCESSING ON *ENTEROBACTERIACEAE* COUNTS ($\log_{10}$ cfu/cm^2) ON LAMB CARCASSES

Where faecal spots occur on beef carcasses after evisceration-trimming or steam-vacuuming may be used as outlined above. Steam-vacuuming may also have a role in decontaminating sheep carcasses after evisceration as the areas involved are small.

Carcass Decontamination

In recent years the meat industry has expressed considerable interest in the meat carcass decontamination systems and a number of these have been approved for use by FSIS (Anon. 1995). A variety of systems have been tested and the effectiveness of many of these have been reported previously (Siragusa 1996) and it is not the intention of the present paper to reconsider the majority of these.

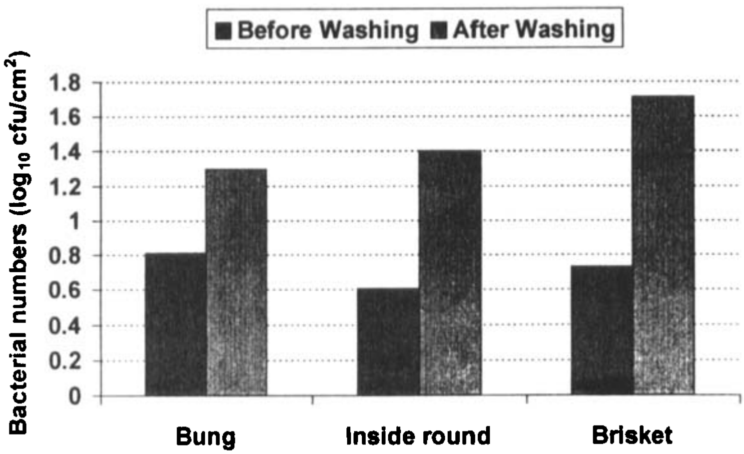
(1) The efficiency of the application of hot or cold water in removing or killing bacteria has been examined by a number of different workers (Kelly *et al.* 1982; Dorsa *et al.* 1996). According to Reagan *et al.* (1996) cold or warm water (35C) is less effective than hot (80C+) and the effects are similar for aerobic and *E. coli* counts (Table 7). Cold water sprays rely on physical removal of bacteria, while bacterial injury or death requires the presence of heat. Hot water systems use up to 40 L of water per carcass, depending on the type of spray used, and decontamination is for 15 to 20 s. The water is filtered and recycled and losses are made up with potable water only. Recently it has been suggested that combined treatments with hot (70C) water at low pressure (20 psi), in combination with high pressure (125 psi) and warm water (30C) give the most effective treatment (Dorsa *et al.* 1996).

TABLE 7.
MEAN AEROBIC AND *E. COLI* COUNTS ($log_{10}cfu/cm^2$) FROM BEEF CARCASSES DELIBERATELY CONTAMINATED WITH FAECAL MATERIAL FROM THE HIDE AND DECONTAMINATED DURING NORMAL SLAUGHTER

	Control	Trimmed	*Washed (28-42C)	*Hot Washed (74-88C)
Aerobic count	4.20[a]	2.88[c]	3.24[b]	2.20[d]
E. coli	2.23[a]	0.63[c]	1.19[b]	0.41[c]

*Washed in on-line automated wash cabinets in a commercial abattoir
Means followed by different letters in the same row are statistically different P<.05.
Data: Reagan *et al.* (1996)

Washing beef carcasses with warm water (35C) may increase contamination levels. Figure 5 shows that washing with a hand-held hose, using a rise and fall stand, increased contamination at a number of sites on beef carcasses. These data indicate that washing redistributed the bacteria more generally over the different sites on the carcasses (McEvoy *et al.* 1997). In experiments where bacterial removal has been demonstrated with warm water, washing was carried out in cabinets, where the direction of water flow, pressure and temperature are all controlled (Reagan *et al.* 1996). Under these conditions positive reductions in cell numbers can be achieved as bacterial redistribution across the carcass is avoided.



Data: McEvoy *et al.* (1997)

FIG. 5. THE EFFECT OF WASHING BEEF CARCASSES WITH WATER AT 35C ON PSYCHROTROPHIC *PSEUDOMONAS* COUNTS ($\log_{10}$ cuf/cm^2) AT DIFFERENT SITES

(2) Recently a commercial on-line decontamination system has become available using steam for short times (6 to 8 s) (Nutsch *et al.* 1997). The effectiveness of this pasteurization in reducing bacterial counts is about the same as hot water washing (Table 8). During steam pasteurization, the temperature of the surface of the carcass reaches 90-96C in about 1 s. After 6-8 s the carcass is cooled with chilled water to rapidly reduce surface temperature (Phebus *et al.* 1997).

TABLE 8.
MEAN TOTAL COUNTS ($log_{10}cfu/cm^2$) ON COMMERCIAL BEEF CARCASSES AFTER STEAM DECONTAMINATION (8 S) AND AFTER CHILLING (29 H)

Carcasses+	Control	Steam Decontaminated	Chilling
Cows	2.19^a	0.84^b	0.94^b
Feedlot cattle	2.14^a	1.03^b	1.09^b

Different superscripts within rows are significantly different P<01
+ Carcasses from cows and feedlot cattle, mostly steers, will have different grades
Data: Nutsch *et al.* (1997)

(3) There is a large body of evidence to show that organic acids can be successfully used to decontaminate meat (Siragusa 1996). It is generally accepted that hot acids are the most effective. Lactic acid is most commonly used and its effectiveness in decontaminating beef carcasses is illustrated in Table 9. This shows that 1% hot (55C) lactic acid applied after dehiding or evisceration at the end of the slaughter process or after both treatments was capable of significantly reducing bacterial counts. When the acid was applied both after dehiding and evisceration the reduction in contamination was significantly better than at either site alone. This confirms the previous observation on the efficacy of preevisceration washing already referred to in Fig. 3.

TABLE 9.
MEAN AEROBIC COUNTS ($log_{10}cfu/cm^2$) ON BEEF CARCASSES SPRAYED AFTER DEHIDING AND EVISCERATION WITH HOT LACTIC ACID

Sampling Time 9h	Control	Treatment With 1% Lactic Acid at 55C		
		Dehiding	Evisceration	*Both
0	3.90^a	2.40^b	2.20^b	1.60^c
72	3.50^a	2.90^{ab}	2.40^{bc}	2.10^c

* Lactic acid sprayed after dehiding and evisceration
Means with a common superscript are not significantly different P< .05
Data: Prasai *et al.* (1991)

In general, decontamination processes using either hot water, steam or hot lactic acid gave reductions in bacterial counts of about 2 logs. This reduction was generally sustained after chilling. Since hot water or steam were as effective as lactic acid or a number of other chemical decontaminating agents in removing bacteria from carcasses, it is difficult to see how they will be used by industry (Siragusa 1996). A number of chemicals, in particular chlorine or organic acids, have the major disadvantage of being highly corrosive. They also add considerable cost, particularly the acids, and environmentally would require costly systems for effective disposal.

The Effects of Line Speed on Carcass Hygiene

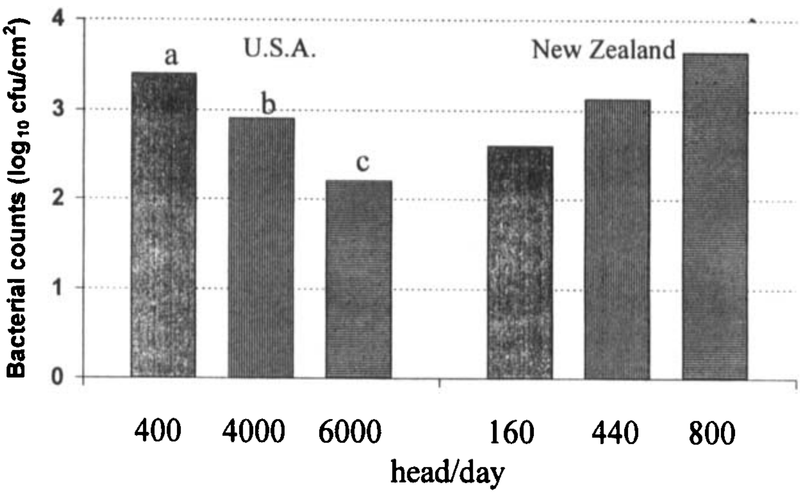
According to Roberts (1980) line speed may have serious implications in relation to carcass contamination. The faster the line operates the more opportunities there are for mistakes to be made and hence more contamination may occur. While this is generally true and it can be demonstrated that the effectiveness of carcass-trimming in removing contamination can be related to line speed, the precise relationship is complicated (Table 10).

TABLE 10.
THE EFFECT OF LINE SPEED ON AEROBIC COUNTS ($log_{10}cfu/cm^2$) ON BEEF CARCASSES TRIMMED UNDER COMMERCIAL CONDITIONS

	Control	Trimmed	Difference
1.	3.50	0.5	3.00
2.	4.20	2.88	1.32
1.	Carcasses stationary during trimming		
2.	Carcasses moving during normal production and trimming. (Rate: 800 - 3,200/day)		

Data: 1. Prasai *et al.* (1995)
2. Reagan *et al.* (1996)

A number of studies have investigated the effects of dressing carcasses on lines at different speeds, from very slow (160 head/day) to very fast (6000/day) (Fig. 6). Data obtained in New Zealand suggests that the mean total counts increase with line speed (Bell 1997). A study in the USA found significantly lower levels of carcass contamination at higher line speeds (Hogue *et al.* 1993). Considering the data of Hogue *et al.* (1993) the authors note a number of unexpected circumstances which may explain this anomalous situation. These include better management systems, a greater level of specialization of labor, leading to fewer cuts and the use of decontamination systems in larger establishments. Decontamination would mask many of the defects made during faster slaughter but presupposes that other plants would not use such systems, which was the case in the New Zealand work (Bell 1997).



Data: **[1]Hogue *et al*. (1993)** **[2]Bell (1997)**

[ab]Means with different superscript letters are significantly different ($P<0.01$)

FIG. 6. TOTAL COUNTS (log_{10} cfu/cm^2) ON BEEF CARCASSES FROM CATTLE SLAUGHTER LINES OPERATING AT DIFFERENT SPEEDS

It is clear that the relationship between line speed and carcass contamination levels is not simple and is influenced by a large number of factors such as operator fatigue, knife skills, length of working day, levels of boredom and the presence/absence of proper management structures (HACCP). The most important aspect is whether or not the operatives have sufficient time to carry out their jobs. The latter is the most crucial element and is recognized in some countries where the speed of the line is regulated by the number of carcasses that an inspector can examine in an hour (Roberts 1980).

The Influence of Technology Advances on Carcass Contamination

It is often assumed that advances in technology or increased automation brings benefits in terms of carcass hygiene. Data in Table 11 broadly support this assumption, and suggests that overall reduction in the extent of carcass handling reduces contamination. In general terms, slaughter practices have developed to incorporate mechanical advances, but the changes in practices and carcass counts are not constant. In a beef plant in Australia during a 27-year period (1937-1964), no changes in bacterial numbers on carcasses were evident (Table 11); however in the succeeding 14 years, a significant improvement was noted (Grau 1979). Similar reduction in beef carcass counts have been recorded in a New Zealand plant (Keeley 1988), but in the United Kingdom modernization of a number of meat plants gave no improvements in carcass hygiene (Hudson *et al.* 1987; Whelehan *et al.* 1986).

Similar inconsistent results have been reported in relation to modernization of sheep slaughter lines in New Zealand. Keeley (1988) reported that carcass hygiene improved in one modernized plant, but not in another (Fig. 7). When two sheep plants in Ireland were examined, after an interval of 17 years, there was a significant deterioration in carcass hygiene in both (Sierra *et al.* 1997). Considerable technological changes had occurred in these plants in recent years with the installation of fleece pullers and an inverted system of carcass dressing.

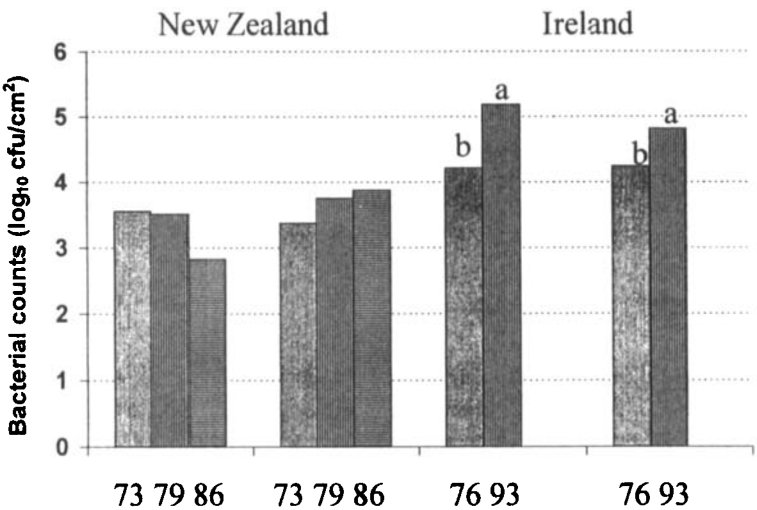
TABLE 11.
INFLUENCE OF CHANGES IN SLAUGHTER TECHNOLOGY ON TOTAL COUNTS ($log_{10}cfu/cm^2$) ON BEEF CARCASSES PROCESSED IN DIFFERENT COUNTRIES

Country	Time	Total Counts	References
	1937	3.88	Grau 1979
Australia	1964	3.90	
	1978	2.79[a]	
	1973	2.85	Keeley 1988
New Zealand	1979	2.10	
	1986	2.16	
	Original line	3.60	
	Modernized line (a)	3.57	Hudson *et al.* 1987
	(b)	3.76	
United Kingdom	Manual line	3.07	Whelehan *et al.* 1986
	Automated line	3.04	

[a]Significantly different $P < .01$)

According to Longdell (1996) and Bell and Hathaway (1996) the inverted system of lamb dressing gives improvements in bacterial numbers on carcasses. That fleece pullers can improve carcass hygiene at some sites has been shown (Field *et al.* 1991) (Table 12), but overall carcass hygiene may deteriorate as a result of faster throughputs, coupled with a deterioration in hygiene standards

(Mackey and Roberts 1993). In summary, though automation can clearly make the slaughter process less labor intensive and technologically more efficient, significant benefits in terms of carcass hygiene are not automatically achieved when such systems are introduced.



Data: Keeley (1988) Sierra *et al.* (1997)

^{a,b} Means with different superscript letters are significantly different (P<0.01)

FIG. 7. INFLUENCE OF CHANGES IN SLAUGHTER TECHNOLOGY ON TOTAL COUNTS ($\log_{10}$/cm^2) ON LAMB CARCASSES PROCESSED IN DIFFERENT COUNTRIES

TABLE 12.
THE EFFECTIVENESS OF A PELT PULLER, COMPARED TO HAND REMOVAL, IN REDUCING TOTAL COUNTS ON LAMB CARCASSES ($\log_{10}$cfu/cm^2)

	Animal Fleece			
Carcass Site	Long		Short	
	Puller	Hand	Puller	Hand
Shoulder	2.46^a	2.15^a	2.55^a	2.32^a
Leg	1.82^a	2.31^b	1.86^a	2.32^b

Different superscripts in the same row differ (P<.05)
Data: Field *et al.* (1991)

CONCLUSIONS

The hide or fleece of the live animal is generally recognized as the single largest source of contamination of beef and lamb carcasses. While decontamination of the live animal presents many practical difficulties, it should be addressed as a priority in relation to pathogen control. The introduction of changes in technology or processing should be assessed in relation to their efficacy in reducing carcass contamination. These changes should be considered in relation to an overall HACCP plan and should only be accepted where there is a proven relationship between a reduction in contamination and the introduction of the new technology.

REFERENCES

ANON. 1993. Generic HACCP for raw beef. National Advisory Committee on Microbiological Criteria for Foods US Department of Agriculture. Food Microbiol. *10*, 449–488.

ANON. 1995. Pathogen reduction: hazard analysis critical control point (HACCP) systems, proposed rule. Federal Register *60*, 6773–6888.

ANON. 1997. Clean Cattle Policy. Department of Agriculture, Food and Forestry, Dublin.

BELL, R.G. 1997. Distribution and sources of microbial contamination on beef carcasses. J. Appl. Microbiol. *82*, 292–300.

BELL, R.G. and HATHAWAY, S.C. 1996. The hygienic efficiency of conventional and inverted lamb dressing systems. J. Appl. Microbiol. *81*, 225–234.

BISS, M.E. and HATHAWAY, S.C. 1995. Microbiological and visible contamination of lamb carcasses according to pre-slaughter presentation status: implications for HACCP. J. Food Prot. *58* (7), 7776–783.

BOLTON, D.J., BYRNE, C. and SHERIDAN, J.J. 1997. The transfer of *Escherichia coli* O157:H7 from the contaminated hide to the carcass during routine slaughter. Unpublished data. The National Food Centre, Dublin.

DICKSON, J.S. 1995. Susceptibility of pre-evisceration washed beef carcasses to contamination by *Escherichia coli O157:H7* and Salmonellae. J. Food Prot. *58*, 1065–1068.

DOLNICK, E.H., LINDAHL, I.L., REYNOLDS, P., TERRILL, C.E. and DICKINSON, H.L. 1970. CPA lethality in sheep at high dose levels. J. Anim. Sci. *31*, 220.

DORSA, W.J., CUTTER, C.N. and SIRAGUSA, G.R. 1996. Effectiveness of a steam-vacuum sanitizer for reducing *Escherichia coli* O157:H7 inoculated to beef carcass surface tissue. Lett. Appl. Microbiol. *23*, 61–63.

FIELD, R.A., KALCHAYANAND, N., ROZBEH, M. and ANDERSEN, M.K. 1991. Influence of a pelt puller on microbiological quality of lamb. Proc. West. Sec., Amer. Soc. Anim. Sci. *42*, 147–148.

GRAU, F. 1979. Fresh meats: bacterial association. Arch. Lebensmittelhyg. *30*, 87–91.

HOGUE, A.T. *et al.* 1993. Bacterial on beef briskets and ground beef: correlation with slaughter volume and ante-mortem condemnation. J. Food Prot. *56*, 110–113, 119.

HUDSON, W.R., ROBERTS, T.A. and WHELEHAN, O.P. 1987. Bacteriological status of beef carcasses at a commercial abattoir before and after slaughterline improvements. Epidem. Inf. *98*, 81–86.

KEELEY, G.M. 1988. The microbiological status of meat from some typical New Zealand meat slaughtering and processing lines. Proc. 34th Internat. Cong. of Meat Sci. and Tech., pp. 504–507, Brisbane, Australia.

KELLY, C.A., LYNCH, B. and McLOUGHLIN, A.J. 1982. The effect of spray washing on the development of bacterial numbers and storage life of lamb carcasses. J. Appl. Bact. *53*, 335–341.

KOCHEVAR, S.L., SOFOS, J.N., BOLIN, R.R., REAGAN, J.O. and SMITH, G.C. 1997. Steam vacuuming as a pre-evisceration intervention to decontaminate beef carcasses. J. Food Prot. *60*, 107–113.

LEACH, T.M. 1971. Preliminary observations on the chemical de-fleecing of sheep as a means of reducing carcass contamination. Proc. Eur. Meet. Meat Res. Workers, pp. 161–166, Bristol.

LEEMON, H. 1997. Australian Meat Technology Safe Seal System 500. Unpublished data. Australian Meat Technology Pty Ltd., 1820 Ipswich Road, Rocklea, Queensland, Australia.

LONGDELL, G.R. 1996. Recent developments in sheep and beef processing in Australia. Meat Sci. *43*, 165–174.

LOWMAN, B.G., SYNGE, B. and CALDOW, G. 1997. Producing clean slaughter cattle. Technical Note, T468 SAC, West Mains Road, Edinburgh, EH9 3JG.

MACKEY, B.M. and ROBERTS, T.A. 1993. Improving slaughter hygiene using HACCP and monitoring. Fleischwirtschaft *73*, 58–61.

McEVOY, J., SHERIDAN, J.J. and McGUIRE, L. 1997. The effect of cold water washing on beef carcass contamination. Unpublished data. The National Food Centre, Dublin.

NESBAKKEN, T., NERBRINK, E., RØTTERUD, O.J. and BORCH, E. 1994. Reduction of *Yersinia enterocolitica* and *Listeria* spp. on pig carcasses by enclosure of the rectum during slaughter. Int. J. Food Microbiol. *23*, 197–208.

NUTSCH, A.L *et al.* 1997. Evaluation of a steam pasteurisation process in a commercial beef processing facility. J. Food Prot. *60*, 485–492.

PHEBUS, R.K. *et al.* 1997. Comparison of steam pasteurisation and other methods for reduction of pathogens on surfaces of freshly slaughtered beef. J. Food Prot. *60,* 476–484.

PRASAI, R.K., ACUFF, G.R., LUCIA, L.M., HALE, D.S., SAVELL, J.W. and MORGAN, J.B. 1991. Microbiological effects of acid decontamination of beef carcasses at various locations in processing. J. Food Prot. *54,* 868–872.

PRASAI, R.K., PHEBUS, R.K., GARCIA ZEPEDA, C.M., KASTNER, C.L., BOYLE, A.E. and FUNG, D.Y.C. 1995. Effectiveness of trimming and/or washing on microbiological quality of beef carcasses. J. Food Prot. *58,* 1114–1117.

REAGAN, J.O. *et al.* 1996. Trimming and washing of beef carcasses as a method of improving the microbiological quality of meat. J. Food Prot. *59,* 751–756.

RIDELL, J. and KORKEALA, H. 1993. Special treatment during slaughtering in Finland of cattle carrying an excessive load of dung: meat hygienic aspects. Meat Sci. *35*, 223–228.

ROBERTS, T.A. 1980. Contamination of meat: the effects of slaughter practices on the bacteriology of the red meat carcass. Royal Soc. Health *100*, 3–9.

SIERRA, M.L., SHERIDAN, J.J. and McGUIRE, L. 1997. Microbial quality of lamb carcasses during processing and the acridine orange direct count technique (a modified DEFT) for rapid enumeration of total viable counts. Int. J. Food Microbiol. *36*, 61–67.

SIRAGUSA, G.R. 1996. The effectiveness of carcass decontamination systems for controlling the presence of pathogens on the surface of meat animal carcasses. In *HACCP: An Integrated Approach to Assuring the Microbiological Safety of Meat and Poultry*. (J.J. Sheridan, R.L. Buchanan and T.J. Montville, eds.) pp. 89–98, Food & Nutrition Press, Trumbull, CT.

SCHNELL, T.D. *et al.* 1995. Effects of post-exsanguination dehairing on the microbial load and visual cleanliness of beef carcasses. J. Food Prot. *58,* 1297–1302.

STAPLETON, P. 1997. Beef and sheep carcass decontamination equipment for the removal of faecal clods and dags from beef and sheep. Personal communication. CSIRO, Brisbane Laboratory, Cannon Hill, Queensland, Australia.

WHELEHAN, O.P., HUDSON, W.R. and ROBERTS, T.A. 1986. Microbiology of beef carcasses before and after slaughterline automation. J. Hyg. Camb. *96*, 205–216.