Journal of Applied Microbiology ISSN 1364-5072

ORIGINAL ARTICLE

Effect of ante- and postmortem hide clipping on the microbiological quality and safety and ultimate pH value of beef carcasses in an EC-approved abattoir

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Keywords
agriculture, food, food processing, legislation, production.

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2007/0896: received 8 June 2007, revised and accepted 22 October 2007

doi:10.1111/j.1365-2672.2007.03670.x

Abstract

Aims: Effect of ante- and postmortem hide clipping on the microbiological quality of beef carcasses.

Methods and Results: Bovine carcasses (362) were tested for indicator micro-organisms and the presence of pathogens. Prior to slaughter, hide cleanliness of each animal was categorized on a scale of 1–5 (clean to dirty). Lowest mean aerobic colony counts (ACC) ($\log_{10}$ 3·0 CFU cm^{-2}) came from carcasses where clipping had been performed in lairage, antemortem. ACC from animals clipped online ($\log_{10}$ 3·2 CFU cm^{-2}) were significantly higher ($P < 0{\cdot}05$) than those clipped in lairage, but comparable to those carcasses from Category 1 and 2 animals. There were no significant differences in the detection of pathogens from any of the carcass groups. Ultimate pH values for carcasses from Category 3 and 4 animals showed clipping animals in lairage, as opposed to online, resulted in a small, but significant increase ($P < 0{\cdot}05$) in pH value (mean pH 5·66 and 5·59, respectively).

Conclusions: Hide clipping does not adversely affect microbiological quality of carcasses, although higher ultimate pH values indicate increases in antemortem stress.

Significance and Impact of the Study: Hide clipping carcasses both ante- and postmortem appears to be an effective intervention to minimize transfer of hide microflora to carcasses during slaughtering operations. Online clipping offers advantages for animal welfare and improves safety for operatives.

Introduction

High numbers of micro-organisms are commonly found on the hides of cattle (Ayres 1955 (cited by Brown 1982); Reid *et al.* 2002a) and contamination with faecal material results in the direct or indirect transfer of enteric micro-organisms to carcasses during the dehiding process (Sheridan 1988). Furthermore, the level of contamination present on the hide has been shown to be correlated with that found on finished carcasses (Byrne *et al.* 2000).

Regulatory authorities in many countries have, therefore, introduced visual grading systems for food animals, including cattle and sheep, presented at the time of slaughter, to assess the degree of coat cleanliness. Typically, those animals that are assessed as clean are slaughtered for human consumption, but those that are considered dirty are either cleaned or rejected (Small *et al.* 2005).

The clean livestock policy was introduced in UK in 1997 following a large scale outbreak of *Escherichia coli* O157:H7, involving multiple fatalities, in Lanarkshire, Scotland a year earlier and subsequent publication of the Pennington Report. The aim of this policy was to ensure a consistent approach to the categorization of animals

presented for slaughter and to minimize the risk of food poisoning caused by bacteria on dirty coats and fleeces of cattle and sheep.

Each animal is assessed against a scale of 1–5, with animals in Categories 1 and 2 being the cleanest and considered safe for slaughter with no further precautions being required. Category 3 animals are rejected at first presentation antemortem and may be dealt with in a number of ways including retention in the lairage on clean bedding to facilitate cleaning/drying and clipping to remove contaminated hair.

Such clipping in the lairage has been identified as a health and safety risk for operatives (Anon 1999) as a result of kicks from the animals in the pens or crushes. It is also possible that stress imposed on the animals during clipping operations could have an adverse effect on the quality of the resulting meat because of higher ultimate pH values being achieved in the muscles from incomplete postmortem glycolysis.

An alternative approach is the application of online clipping, where hides are clipped postmortem after stunning and bleeding, but before dehiding, to remove visible dirt, particularly along the ventral midline area where the initial knife opening occurs. Clippers attached to flexible vacuum hoses are typically used for such operations and dirt and hair are removed from the hide surface by the negative pressure.

The potential application of online clipping in UK remains unclear, since the EU Hygiene Regulations (EC No. 852/2004, EC No. 853/2004 and EC No. 854/2004) came into force on 1 January 2006 were more explicit in making the responsibility for the production of safe food lie with the food business operator. Moreover, EC Regulation 853/2004 (H2) requires that all animals should be clean before being accepted into the slaughterhouse premises. EC Regulation 854/2004 (H3) stipulates that animals with hides, skins or fleeces posing an unacceptable risk of contamination to meat during slaughter cannot be slaughtered for human consumption unless they are cleaned beforehand. Thus, it would seem that online clipping (postmortem) is precluded on these two accounts.

The commercial scale application of online clipping has not, to the authors' knowledge, been investigated in the context of the hygienic production of carcasses. There is a need therefore to assess the effects that hide clipping operations have on the microbiological status of carcasses. Therefore, the main aim of this study reported here was to investigate the effects of ante- and postmortem hide clipping on the microbiological quality and safety of beef carcasses in comparison with carcasses derived from clean animals processed without any such interventions. A secondary objective was to carry out environmental microbiological monitoring (air and surfaces samples) within the slaughterhouse to investigate whether clipping operations resulted in a change in microbial populations within this environment.

Materials and methods

Carcass selection

A total of 362 beef carcasses (all from animals under 30 months of age) were sampled over an 8-month period (26 August 2004 to 1 March 2005) at one of the EU-licensed abattoirs in Northern Ireland slaughtering only bovines. This plant processes approx. 50 animals per hour and has the facilities for hide clipping both ante- and postmortem (i.e. in the lairage or online, respectively).

Prior to slaughter, the Official Veterinary Surgeon (OVS) in the plant assessed the cleanliness of each animal by allocating an Hygiene Assessment Score. Category 1 and 2 animals were slaughtered with no further precautions being taken. Category 3 and 4 animals, which are classed as being dirty, requiring special provisions to be taken before they may be slaughtered, were either clipped antemortem in the lairage using sheep shearers (Heinger, Dursley, UK) or postmortem online (after stunning, shackling and bleeding but before hide pulling) using pneumatic sheep shearers (CTS Equipment, Cashel, Co. Tipperary, Ireland). The selection of which animals were clipped in the lairage or online was made randomly by the OVS. Category 5 animals were rejected by the OVS and were thus excluded from this study. The breakdown of the number of carcasses sampled according to category and treatment are presented in Table 1.

The study commenced in the summer when cattle were coming straight off pasture, and as the sampling period progressed into the autumn and winter, animals were from housed conditions. In total, 20 visits were made to the plant for carcass sampling and during the first six visits (up to and including 18 October 2004) all animals tested were Category 1 or 2. In subsequent visits, progressively more of the animals being presented were Category 3 and 4.

Carcass sampling

Carcasses were temporarily diverted to the detained chill after inspection, but before electrical stimulation and chilling, to facilitate microbiological sampling. Single excision samples were taken from four sites on one side of each carcass using the sites of the rump, brisket, flank and neck as described in Commission Decision 2001/471/EC of 8 June [Standard Rules of Northern Ireland 2002 No. 217 Meat (Hazard Analysis and Critical Control Point, HACCP) Regulation (Northern Ireland

Table 1 Breakdown of the numbers of beef carcasses sampled microbiologically and for ultimate pH values according to HAS categorization and location of hide clipping

Carcass category	Clipping status/ location	Total number of carcasses sampled	Number of carcasses sampled microbiologically (pooled sample)	Number of carcasses sampled microbiologically (individual sites)	Number of carcasses tested for ultimate pH value	Number of carcasses tested for selected pathogens
Category 1	Unclipped	60	50	10	0	57
Category 2	Unclipped	60	50	10	0	56
Category 3	Lairage	61	51	10	55	61
Category 3	Online	60	50	10	52	60
Category 4	Lairage	60	50	10	52	60
Category 4	Online	61	50	11	53	61
Total		362	301	61	212	355

2002)]. To eliminate bias, the side being sampled between each carcass was alternated.

A sterile core borer (5 cm^2) was used to cut the surface and tissue plugs (approx. 2 mm thick) were removed aseptically using sterile forceps and scalpels. The four plugs from each animal were combined in one labelled sterile stomacher bag to make a pooled sample, which was then transported to the laboratory in a chilled container at a temperature of <4°C for further analysis to determine the levels of micro-organisms present. A subset of 61 carcasses (Table 1) were sampled as above, but individual tissue plugs from each sampling site were placed into separate stomacher bags and analysed independently to provide data on the contribution of each site to the microbial populations recovered.

The opposite side of the carcass to that tested by excision was sampled for the presence of selected pathogens using a sponge swab technique. This was performed on a total of 355 carcasses (Table 1). Based on a risk assessment conducted in conjunction with the plant OVS, swab samples were taken from the rump and brisket regions, as these were considered to be the most likely sites of contamination during slaughtering and dressing operations.

Sterile abrasive swabs (4 cm × 8 cm; whirl pak spec-i-sponge bag; NASCO, Ft. Atkinson, WI) were premoistened with 10 ml maximum recovery diluent (MRD; Oxoid), before being held using the sterile glove provided to sample a 10 × 50 cm area of the brisket and a 20 × 25 cm area of the rump, thus giving a total sampling area of 1000 cm^2 per carcass. A ruler was held next to the sampling areas to approximate their dimensions. Each sponge swab was rubbed over all parts of each sampling area, using at least 10 strokes in each direction, first horizontally, then vertically and finally diagonally; first for the brisket, before turning it over and using the other side of the swab to repeat the process for the rump. Swabs were placed into individually labelled bags and transported to the laboratory in a chilled container at a temperature of <4°C. Within 5 h of the sample being taken, 50 ml of buffered peptone water (Oxoid) was added to commence the microbiological analysis.

Ultimate pH value

The pH value of meat samples (*Longissimus dorsi* muscle, 24 h postmortem) from Category 3 and 4 animals clipped before and after slaughter was measured directly in 213 carcasses using a probe type pH meter (Orion, 130A+; AGB Scientific, Dublin, Ireland).

Environmental sampling

Surface sampling

Ten surfaces were selected for microbiological analysis, based upon an audit of surfaces likely to come into contact with carcasses, advice from the OVS and the abattoir's own hygiene protocols. These surfaces were swabbed during production (i.e. dirty) and then again after subsequent cleaning, but before production recommenced. This was performed on seven different occasions over a 6-month period (14 October 2004 to 1 March 2005). The sample locations selected, in order of occurrence on the production line were: online clipper wall; hide pull wall (wall opposite hide pull at approx. 1·5 m from the floor); rodding tool; brisket saw stand (lowest central part of stand behind the brisket saw); brisket saw blade; carcass saw blade; spinal hoover rail; spinal cord hoover nozzle; carcass hoover nozzle; and electrical stimulator wall (wall at entrance to electrical stimulator, sample taken at approx. 0·5 m from the floor) (Fig. 1). The 'hoover nozzles' refer to the vacuum system used to remove debris from the area.

Each surface was swabbed using the wet/dry swab technique. Wherever possible, a sterile metal template (25 cm^2) was used to mark out the sampling area. A 'jumbo' cotton swab (Technical Services Consultants Ltd) moistened in MRD was passed over the surface at least 20

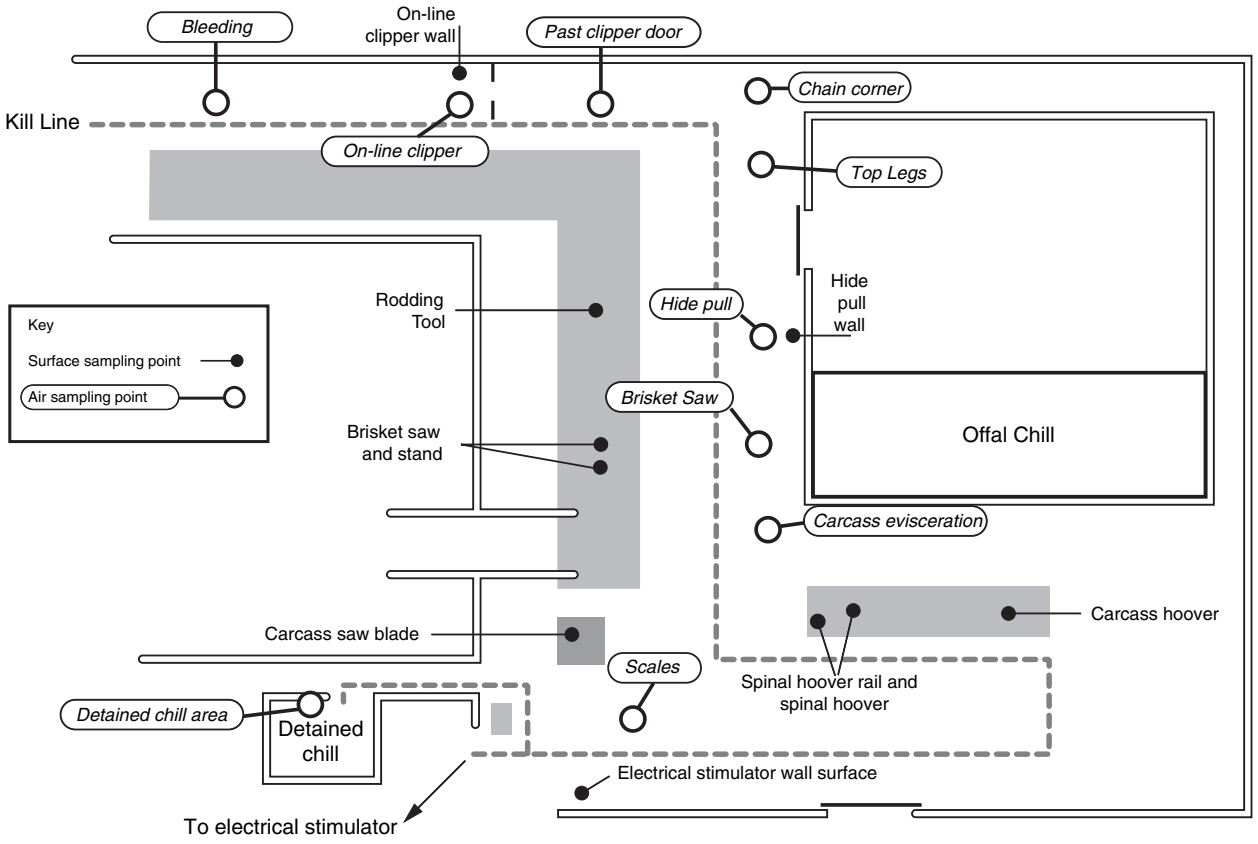

Figure 1 Schematic diagram of factory floor, showing surface and air sampling points.

times each way, horizontally, vertically and diagonally, while rotating the swab between each pass. This process was then repeated using a separate dry swab. The tips from both swabs were aseptically removed and placed into labelled containers containing 10 ml of MRD and maintained at <4°C until being processed in the laboratory.

Air sampling

Air samples were taken from 11 locations distributed throughout the production line on six occasions over a 2-month period (10 February 2005 to 21 March 2005) using an RCS centrifugal air sampler (Biotest Diagnostics, Solihull, W. Midlands, UK) for a period of 30 s. Strips of three types of media were used in the device according to the manufacturer's instructions [Tryptone Soy Agar (TSA), Rose Bengal Agar and McConkey Agar] at each location. Air sampling locations are indicated in Fig. 1.

Microbiological analyses

Excision samples

Following collection at the abattoir, excision samples were kept at 4°C overnight and processed the next morning by adding 100ml of MRD to the pooled samples and stomaching (Bagmixer; Interscience, London, UK) for 1min. Further decimal dilutions were prepared in MRD and aerobic colony counts (ACC) were performed according to ISO 4833, by adding 1ml volume of the sample dilutions to duplicate plates and pour-plating using Plate Count Agar (Oxoid), before incubating at 30°C for 48 h. Enterobacteriaceae counts (following ISO 21528-2) were obtained by pour-plating 1ml volume of the sample dilutions in duplicate using Violet Red Bile Glucose Agar (VRBGA; Oxoid), which was subsequently over-poured with VRBGA before incubating at 37°C for 24 h.

Excision samples from individual sites were processed using the same protocol described above, except that an initial volume of 25 ml MRD was added prior to homogenization. A simulated pooled sample was further created from these samples by combining equal volumes of each homogenate produced from the four individual sites before plating, as described above.

Pathogen testing

Sponge swab samples were analysed according to Animal By-Products Northern Ireland 2003 standards and

recorded as presence/absence data for the range of pathogens tested. *Salmonella* spp. were tested for using an impedance-based method employing the RABIT [Animal By-Products Regulations (NI) 2003] and identified using the Kauffmann-White Scheme. Detection of *Staphylococcus aureus* was performed according to BS 4285: Sections 3.10.1 and 3.10.2. *Listeria* spp. was detected and speciated according to BS ISO 11290-1:1997. The presence of *E. coli* was determined using ISO 16649 Part 2: 2001.

Surface sampling

Environmental surface swabs were vortexed (for 30 s) in the MRD present in the transport container, before being subjected to ACC and Enterobacteriaceae counts, as outlined above for excision samples.

Air sampling

Agar strips were enumerated after incubating at 30°C for 1–5 days (TSA and McConkey agars, for ACC and Enterobacteriaceae counts, respectively) and at 25°C for 3–7 days (Rose Bengal Agar, for yeast and mould counts). The detected number of organisms per unit volume of air was calculated to give the number of colony forming units per cubic meter (CFU m^{-3}).

Data analysis

Data were analysed individually using ANOVA and by combining results obtained from clean (Categories 1 and 2) cattle and dirty (Categories 3 and 4) cattle as factorial identities.

Results

Pooled carcass excision samples

There was no significant difference ($P > 0{\cdot}05$) in the ACC obtained from clean cattle (Categories 1 and 2) and dirty cattle (Categories 3 and 4), clipped either in the lairage or online (Table 2). Further statistical analysis was carried out which examined carcasses from Categories 3 and 4 as factorial identities according to the location of clipping (lairage or online). This showed that lairage-clipped animals produced carcasses with the lowest counts overall ($P < 0{\cdot}05$) (Table 3). Enterobacteriaceae counts were beneath the detection sensitivity of the pour-plate method employed for the majority of carcasses tested. Analysis of the data obtained showed no statistically significant ($P > 0{\cdot}05$) associations between the Enterobacteriaceae populations recovered and animal category or clipping location and are therefore not presented further.

By applying the bacterial performance criteria laid out in Commission Decision of 26 April 2004 (2004/379/EC) amending Decision 2001/471/EC, the proportions of daily log mean counts obtained from carcasses falling into acceptable (3·5 $\log_{10}$ CFU cm^{-2}), marginal (3·5 – 5·0 $\log_{10}$ CFU cm^{-2}) and unacceptable (>5·0 $\log_{10}$ CFU cm^{-2}) ranges for ACC were determined (Table 4). Unacceptable microbial populations were enumerated on carcasses produced from aggregated data for Category 1, 2 and 3 animals, but none of the daily log mean values for Category 4 animals, clipped either in the lairage or online, were at an unacceptable level.

Table 2 Overall mean aerobic colony counts (ACC) for pooled carcass samples, removed by excision according to category of animal and whether clipped in the lairage or online

Carcass category	Clipping location	$\log_{10}$ CFU cm^{-2}
Category 1	Unclipped	3·1
Category 2	Unclipped	3·3
Category 3	Online	3·3
Category 3	Lairage	3·0
Category 4	Online	3·2
Category 4	Lairage	3·0

Least significant difference at 5% level = 0·3 $\log_{10}$ CFU cm^{-2}.

Table 3 Analysis of overall mean ACC (using factorial identities) for pooled carcass samples categorized by animal cleanliness and clipping location

Carcass category	Clipping location	$\log_{10}$ CFU cm^{-2}
Category 1	Unclipped	3·1
Category 2	Unclipped	3·3
Category 3 + 4	Lairage	3·0
Category 3 + 4	Online	3·2

Least significant difference at 5% level = 0·2 $\log_{10}$ CFU cm^{-2}.

Table 4 Application of the bacterial performance criteria laid out in Commission Decision of 26 April 2004 (2004/379/EC) amending Decision 2001/471/EC, against daily $\log_{10}$ mean ACC obtained from carcasses categorized by animal cleanliness and hide clipping location*

Carcass category	Clipping location	Acceptable (%)	Marginal (%)	Unacceptable (%)
Category 1	Unclipped	69·4	27·1	3·5
Category 2	Unclipped	58·3	38·3	3·4
Category 3	Lairage	71·0	25·4	3·6
Category 3	Online	67·7	30·5	1·8
Category 4	Lairage	84·5	15·5	0·0
Category 4	Online	67·3	32·7	0·0

*Acceptable (3·5 $\log_{10}$ CFU cm^{-2}), marginal (3·5 – 5·0 $\log_{10}$ CFU cm^{-2}) and unacceptable (>5·0 $\log_{10}$ CFU cm^{-2}).

Individual carcass sites

Analysis of samples taken from the four individual carcass sites and tested independently demonstrated that ACC varied according to sampling location on the carcass (Table 5). Samples taken from the brisket had significantly ($P < 0{\cdot}05$) higher ACC than those obtained from the flank. Enterobacteriaceae populations measured on neck samples were significantly ($P < 0{\cdot}05$) higher than those recovered from the rump and flank. In each case, the ACC and Enterobacteriaceae populations on individual carcass sites were not affected by the category of the animal or whether the hide had been unclipped, clipped in the lairage or clipped online ($P > 0{\cdot}05$).

Pathogen detection

No statistically significant ($P > 0{\cdot}05$) differences were recorded in the detection of pathogens from carcass surfaces according to the category of the animal or clipping status (Table 6). The detection of *Staph. aureus* only on carcasses produced from Category 1 or 2 animals and the high prevalence of *L. monocytogenes* on carcasses derived from Category 1 animals (21%) may suggest that clipping either ante- or postmortem plays a role in preventing the transfer of pathogens from hides to carcass surfaces.

Table 5 Overall microbial populations recovered from four individual carcass sites, tested by excision from 61 bovine carcasses

Sampling site	ACC ($\log_{10}$ CFU cm^{-2})	Enterobacteriaceae ($\log_{10}$ CFU cm^{-2})
Neck	3·6	0·8
Rump	3·6	0·3
Flank	3·4	0·3
Brisket	3·9	0·6
LSD*	0·3	0·3

*LSD, least significant difference at 5% level.

Ultimate pH value

Ultimate pH values were measured on 213 carcases from Category 3 and 4 animals. Of these, 106 came from animals clipped in lairage and 107 from animals clipped online. Clipping animals in the lairage, as opposed to online, resulted in small, but significant ($P < 0{\cdot}05$) increased ultimate pH values (mean pH value of 5·66 compared to 5·59). This increased pH value suggests an increase in stress preslaughter. It can be concluded that this increase in stress was a result of clipping in the lairage as other factors prior to arrival at the abattoir, such as a dirty production environment may be considered to be have been constant between the treatment groups given that animals were randomly selected by the OVS.

Surface sampling

The efficacy of cleaning within the abattoir was confirmed by statistically significant ($P < 0{\cdot}05$) differences being recorded between dirty and cleaned surfaces (mean ACC values of log 4·1 CFU cm^{-2} and log 3·0 CFU cm^{-2}, respectively). A highly significant difference ($P < 0{\cdot}01$) between the sampling locations was demonstrated overall (Table 7). ACC results for the rodding tool, rails and carcass hoover nozzle were significantly ($P < 0{\cdot}05$) higher than the other sampling locations but not significantly ($P > 0{\cdot}05$) different to each other. Enterobacteriaceae populations recovered from the rodding tool, were significantly ($P < 0{\cdot}05$) higher than all other sample locations. No significant ($P > 0{\cdot}05$) differences in the surface contamination levels were recorded over time.

Air sampling

For each microbial population analysed, the number of micro-organisms recovered in air samples declined along the production line (Fig. 2). For the purpose of analysing

Table 6 Detection of selected pathogens on carcass surfaces using an abrasive sponge swab techniques

			Number of positive samples								
Carcass category	Clipping status/ location	Number of carcasses tested	*Salmonella* spp.	*Listeria innocua*	*Listeria welshimeri*	*Listeria grayi*	*Listeria monocytogenes*	*Listeria seeligeri*	*Listeria* spp.	*Staphylococcus aureus*	*Escherichia coli**
Category 1	Unclipped	57	0	1	31	0	12	0	0	1	40
Category 2	Unclipped	56	0	6	35	1	4	0	1	2	40
Category 3	Lairage	61	0	9	38	0	5	1	0	0	39
Category 3	Online	60	0	5	42	0	4	0	0	0	34
Category 4	Lairage	60	0	10	39	1	2	0	0	0	32
Category 4	Online	61	0	12	40	0	3	0	0	0	38

*Includes all *Escherichia coli*, some of which may be pathogenic.

Table 7 Overall mean values for microbiological environmental surface sampling in a cattle slaughtering plant

Location type	Number of replicates	ACC (log_{10} CFU cm^{-2})	Enterobacteriaceae counts (log_{10} CFU cm^{-2})
Hoover nozzles	36	4·0	1·3
Saws	36	3·1	0·3
Rodding tool	18	4·5	2·4
Rails	36	3·5	1·1
Walls	54	3·2	0·1
LSD*		0·9	0·6

*LSD, least significant difference at 5% level.

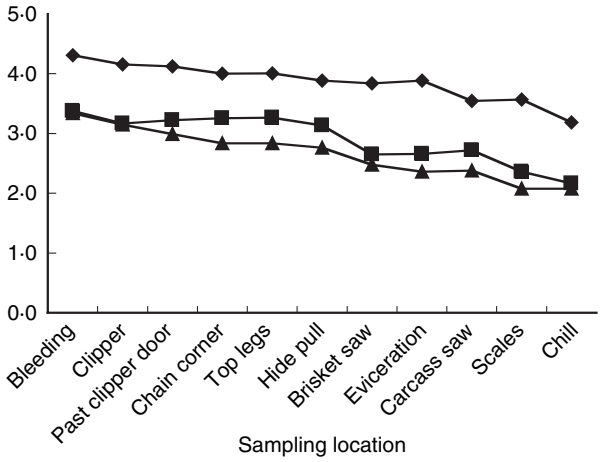

Figure 2 Recovery of microbial populations from air samples obtained at 11 sampling points along a cattle slaughtering line, tested on six occasions. (♦) ACC counts (LSD at 5% = 0·20); (■) yeast and moulds (LSD at 5% = 0·40); (▲) Enterobacteriaceae counts (LSD at 5% = 0·34).

the results obtained, the production line was divided into groups of locations with similar counts, which were not statistically different to each other.

With respect to ACC populations recovered from air samples, the highest counts were obtained in the area concerned with slaughtering the animal, i.e. stunning, shackling, bleeding and online clipping (when practised). The number of micro-organisms recovered from the air in this area were significantly ($P < 0·05$) higher than those observed in other sampling locations along the production line but each point within this area was not significantly ($P > 0·05$) different to the others. Similarly, ACC were obtained from air samples taken in the area defined by the chain corner to the evisceration section. This region is where most of the external carcass dressing takes place, but is separated from the slaughtering area by a 90° turn in the line at the chain corner and a curtain of air produced by fans resulting in a counter-flow of air relative to the direction of the production line. In the vicinity of the carcass saw and scales, there was a further significant ($P < 0·05$) decrease in the ACC recorded. The counts obtained in the detained chill area were the lowest overall and significantly ($P < 0·05$) different from the 10 other locations.

Populations of yeasts and moulds recovered from air samples taken from the first six locations (from the bleeding area up to and including the hide puller) showed that these points were not significantly ($P > 0·05$) different to each other but were significantly ($P < 0·05$) higher than the remainder of those further down the production line. The greatest difference between two adjacent sampling points occurred between the hide pull and the brisket saw.

Enterobacteriaceae populations recovered from air sampled in the bleeding area (which had the highest counts overall) and in the vicinity of the online clipper were significantly ($P < 0·05$) higher than all other sampling locations. Samples taken just past the clipper door were not significantly ($P > 0·05$) different from those taken up to and including the hide puller.

Discussion

Online clipping is an attractive proposition for the meat industry in terms of the advantages that it offers under animal welfare and health and safety grounds compared to clipping in the lairage. Concerns that online clipping activities may result in higher rates of transfer of micro-organisms from hides to carcass surfaces and generally contaminate the processing environment have limited its introduction. Before this investigation, no study had investigated the effects of online clipping under normal commercial operations and the efficacy of online clipping operations in general has not been widely investigated in the published literature. In one small study involving 30 bovine hides reported by Small *et al.* (2005), clipping was shown to result in higher (highly statistically significant ($P < 0·001$)) postclipping microbial levels on the hide. These results were interpreted by these authors as being a result of (i) the generation of dust during the clipping and consequent microbial spread, (ii) the loosening of bacteria on hair making them more recoverable by swabbing and/or (iii) the possible higher numbers of bacteria on skin as compared to hairs. This study did not investigate the microbiological quality of the carcasses following hide clipping and hide removal and so the potential for transfer of organisms to meat surfaces remains unknown. It is also unclear whether these authors used a clipper with a vacuum attachment to facilitate the removal of dirt and hair. Other online hide decontamination procedures have been described in the literature, including chemical dehairing (Nou *et al.* 2003) and chemical washes such as

sodium hydroxide or phosphoric acid (Bosilevac *et al.* 2005).

The data reported in the present study have demonstrated that under production conditions in the particular abattoir investigated, online clipping of hides produced carcasses with comparable numbers of micro-organisms to those derived from clean animals. The fact that Category 4 animals clipped both ante- and postmortem yielded carcasses with overall lower ACC than equivalent carcasses from Category 3 animals is perhaps surprising. It could be speculated that such Category 4 animals were subjected to more extensive clipping than Category 3 animals, perhaps leading to an additional benefit in terms of limiting the transfer of micro-organisms between hides and carcasses and further vindicating the application of hide clipping to assist in hygienic beef production.

Hide surfaces have been recognized as significant sources of micro-organisms, with counts as high as 9·0 $\log_{10}$ CFU cm^{-2} being reported (Jericho *et al.* 1996b). With such high numbers of micro-organisms present it is highly likely that a proportion of this microflora will be transferred to carcass surfaces during dressing operations. In the study reported here, analysis of individual carcass sites demonstrated that highest ACC values were obtained from the brisket and rump regions, thus providing partial validation of the selection of these two sites for pathogen detection. The fact that highest Enterobacteriaceae counts were obtained on the neck and brisket regions suggests that the neck may have been a useful third site to perform pathogen testing.

Reid *et al.* (2002b) concluded that the most contaminated areas of the beef carcass with pathogens were the brisket, followed by the flank and then the rump regions in three abattoirs in the South-West of England. These authors noted considerable differences in the design and operation of these plants. In the study reported here, it had been noted that brisket and neck areas were vulnerable to contact with other surfaces, carcasses and personnel, possibly leading to increased potential for microbial contamination. Such correspondence between practices on the production line and the microbiological data produced provides further credence to the outcomes from this study. Moreover, high numbers of micro-organisms would be expected to be present on the brisket, as the initial cut through the hide during dehiding operations is made at this point and the potential for transfer of organisms from the hide to carcass surface considerable.

The reliability of visual assessment of individual animals has been questioned by Small *et al.* (2005). It has been reported that even visually clean cattle can carry pathogens such as *E. coli* O157:H7 and *Salmonella* spp. (Reid *et al.* 2002b). Indeed, in the study reported here pathogens were detected on carcasses derived from clean animals in Categories 1 and 2 at higher rates than from clipped animals. The high prevalence of *L. monocytogenes* in carcasses derived from Category 1 animals is in marked contrast to an earlier study of cattle in Northern Ireland by Madden *et al.* (2001) where *L. monocytogenes* was absent on all carcasses. Data from a study of pooled beef samples in Canada gave a prevalence of *L. monocytogenes* of almost 13% (Jericho *et al.* 1996a). It is unclear, however, whether the levels of *L. monocytogenes* on beef carcass surfaces may be an emerging issue in Northern Ireland. It would be interesting to continue this work to identify whether pathogens present on carcass surfaces were transferred from the hide or from different sources.

One of the reasons proposed by Small *et al.* (2005) for the higher microbial levels on hide surfaces after clipping they reported was that generation of dust during clipping may have resulted in microbial spread. Analysis of environmental sampling data in the study reported here demonstrated that such an effect was not observed during online clipping activities. It can be concluded from all available data that online clipping was effective in the hygienic production of beef carcasses by not adversely affecting the microbiology of carcasses relative to those produced from unclipped animals.

It should be noted, however, that it may not be possible to directly transfer online clipping operations to other slaughtering lines with such satisfactory results. Murray *et al.* (2000) found that the performance varied considerably among a number of abattoirs surveyed. Indeed, Prendergast *et al.* (2004) concluded that air was a potential vector of bacterial contamination in abattoirs and that design of slaughtering lines significantly affects the extent and transfer of airborne contamination. Separating 'dirty' and 'clean' areas by the location of a wall or directed airflow are effective ways of reducing airborne bacteria. The abattoir in the study reported had a partition just after the online clipper and a 90° turn in the production line, in conjunction with counterflow of air relative to the direction of the line, to minimize microbial transfer.

There has been considerable interest worldwide in the decontamination of carcasses and fresh meat (Huffman 2002; Koohmaraie *et al.* 2005) by physical or chemical methods, or a combination of both. Such approaches run contrary to the Clean Livestock Policy in operation in the UK, where the objective is to present clean animals for slaughter. Evidence would suggest that this is not always possible, depending upon climatic conditions prevailing, type of ground the animals have come off and design characteristics of any cattle houses used. Here, we report that the intervention of online hide clipping may be an effective approach to further protect public health through promoting the hygienic slaughter of cattle and thus serve as a useful adjunct to the Clean Livestock Policy.

Acknowledgements

This work was funded by the Department of Agriculture and Rural Development for Northern Ireland. Ms Sarah McCormick, Mr Andrew Lowry and Ms Pam Scates are thanked for their excellent technical support.

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