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Hygiene aspects of modern poultry chilling

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Abstract

An evaluation was made of six commercial poultry chilling systems in relation to factors affecting microbial contamination of carcasses. These systems included water immersion chilling, air chilling and air chilling with evaporative cooling using water sprays. Samples of neck skin and body cavity were taken from carcasses, together with samples from the chilling environment. These were examined for total aerobic mesophilic microbes and counts of presumptive coliform bacteria and *Pseudomonas* spp. at specific points in the chilling process. Physical measurements included surface and deep-muscle temperatures of carcasses, water temperatures and chlorine concentrations in the immersion system and air speed and temperature during air chilling. The results obtained for water immersion chilling confirmed previous experience that the washing effect reduces microbial contamination of carcasses, although initially the numbers of pseudomonads tended to increase. The air chillers varied in design and mode of operation, but had little overall effect on microbial contamination of the skin. When a completely dry process was used, microbial numbers were reduced approximately ten-fold in the body cavity. However, the use of water sprays tended to increase contamination of the cavity, while relatively heavy spraying using non-chlorinated water, resulted in a substantial increase in the numbers of pseudomonads. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

In the UK two main methods are commonly used for primary chilling of poultry carcasses. Those carcasses intended for freezing are sometimes chilled by means of continuous, in-line, water-immersion systems. The other type of chilling system is basically a dry process that utilises cold air, either in a chill-room or an air-blast tunnel. Although air-chilling has become increasingly popular in the UK, reflecting the growth in demand for fresh poultry, it is often modified to incorporate fine water sprays in the first stage. This modified process, known as 'evaporative chilling', utilises the extra cooling effect that occurs as water evaporates from the

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carcass surface. The process also minimises carcass weight loss. Studies on air-chilling have sometimes shown a reduction in microbial contamination of carcasses by the end of the process; for example, lower counts were observed by Berner et al. (1969), while Knoop et al. (1971) found that the reduction was confined to psychrotrophic bacteria. On the other hand, Lahellec et al. (1973) could detect neither qualitative nor quantitative effects of air-chilling on the carcass microflora. In an EEC study involving eight Member States, (Report, 1978), air-chilling produced no changes in levels of carcass contamination and no effect on shelf-life in comparison with water-chilling, although only neck skin samples were examined. There is less information in this respect on evaporative chilling, although Stephan and Fehlhaber (1994) reported no change in the level of microbial contamination on the skin when the samples were macerated although counts obtained following rinse sampling fell during chilling. Graw et al. (1997), using rinse sampling, found a 0.5 $\log_{10}$ reduction in the microbial load on the skin but observed no such effect in relation to the abdominal cavity. The work reported here was concerned with the three systems of poultry chilling used in the UK, i.e. water immersion, dry air, and evaporative chilling, and their effects on the microbial load on the carcass neck skin and in the body cavity. The role of water sprays on microbial contamination and dispersal was also studied in four chillers with varying degrees of water usage.

2. Materials and methods

2.1. Details of chilling systems studied

Six chilling systems were studied while in normal commercial use. The main features of these systems, designated A–F, are summarised in Table 1. The water chiller (A) was a conventional, counterflow, three-stage unit, that was operating in accordance with the Poultry Meat Hygiene Regulations (Statutory Instrument, 1995) with respect to water usage. The water was chlorinated to give a mean total residual of 45 mg/l, with 20 mg/l in the final unit. The temperature of the water ranged from 15.9°C at the carcass entry point to 5.1°C at the chiller exit. The residence time for carcasses was about 40 min. The residence time in the air chillers varied according to carcass size, staff break times, line stoppages and whether or not carcasses were stored in the chiller overnight. The air chillers (manufactured by Pennine Environmental Services Ltd., Pudsey, W. Yorks, UK) all ran at a nominal 3°C. Chiller C was a 'clipbar' type in which carcasses were hung in horizontal rows which moved in sequence through a chilling tunnel, with a residence time that was generally <90 min. In the four 'Ventstream' chillers, carcasses moved through a chill room on a continuous looped shackle line (residence time also generally <90 min). Water sprays were used in a partly separated prechill area in two of the air chilling systems (D and E) and in the first section of

Table 1
Description of chillers investigated

	Chilling system code					
	A	B	C	D	E	F
Chill method	Water	Air	Air	Air	Air	Air
Chiller type	Spin	Spiral Ventstream	Clipbar	Standard Ventstream	Standard Ventstream	Standard Ventstream
Separate pre-chiller	NO	NO	NO	YES	YES	NO
Nominal pre-chill Temperature °C	NA[a]	NA	NA	10	10	NA
Water spray	NA	YES	YES	YES	YES	NO
Spray cabinet	NA	YES	NO	NO	NO	NA
Chlorination of water	YES	YES	YES	YES	NO	NA
Intensity of spray	NA	light	moderate	moderate	heavy	NA

[a] Not applicable.

the clipbar tunnel (C). In the spiral Ventstream chiller (B) the carcasses passed through two spray cabinets at approximately the 25% position (see Section 2.2), where low volumes of water were applied. Chlorinated water (50 mg/l) was used in the sprays in chillers B, C and D (Table 1).

2.2. Protocol for examination of chilling systems

Three trials were carried out to investigate the effects of chilling in the different systems on total viable counts (TVC) and the counts of presumptive coliforms and pseudomonads recovered from neck skin and body cavity samples. These samples were taken at points where approximately 0%, 25%, 50%, 75% and 100% of the chilling process had been completed. Surface and deep muscle temperatures were also monitored at these points with a digital thermometer (Digitron Instrumentation Ltd, Hertford, Herts, UK). In Chiller B, however, the 75% point was inaccessible on safety grounds. With the water chiller, TVC and counts of presumptive coliforms and pseudomonads were determined for both the water and the chicken carcasses. The deep-tissue and surface temperatures of the carcasses were measured, as well as the temperature and levels of total and free residual chlorine in the chill water (Camlach Hach colorimeter with DPD indicators, Camlab, Cambridge, UK). For air chillers, the same three groups of microbes were monitored on the carcasses, in the air and in the environment. The air temperature and air movement were also studied at each sampling site and in a matrix pattern over the whole chiller using a sonic anemometer (Gill Instruments, Lymington, Hants, UK). This recorded vertical, longitudinal and lateral speeds, 150–200 mm below the carcasses. Microbial airborne and waterborne contamination was assessed by use of air samplers and settle plates (see below).

2.3. General methods of microbiological examination

2.3.1. Sample collection

The following types of sample were taken at the processing plants. Where appropriate, samples were collected in pre-chilled diluent and transported to the laboratory in an insulated box containing ice, where they were held at 1°C in a chilled cabinet until examination the next day.

2.3.1.1. Neck skin

Using aseptic precautions, approximately 10 g of skin were removed and transferred to a sterile polythene bag.

2.3.1.2. Body cavity

A large cotton-wool swab with a wooden shaft (Medical Wire, Corsham, UK) was wiped all round the body cavity and the tip broken off into 10 ml Oxoid Maximum Recovery Diluent (MRD), containing glass beads and pre-chilled to 0°C.

2.3.1.3. Environment

Areas of approximately 50 cm^2 on floors and parts of chiller equipment were sampled using plain dry cotton-wool swabs, as above.

2.3.1.4. Aerosols and carcass drip (Fig. 1)

Three air samplers with an intake of 20 l/min (Burkard Manufacturing Co Ltd, Rickmansworth, UK) were used in the air chillers, each containing one of the three media described below. The three samplers were placed side by side along the longer length of a tray 600×400 mm. The samplers were shielded from carcass drip by a steel sheet suspended 150 mm above their top surface. In parallel to the samplers, two sets of plates were placed in the tray. The tray was positioned 150–200 mm below the carcasses so that any drips fell on one set of plates while the second set was offset so that they only received particles and microbes, which were present in the air or from, deflected droplets. The plates and samplers were exposed for 5 min at each site.

2.3.1.5. Water

Samples were taken from the water chiller and from the water sprays in the air chillers. Sterile bottles containing a crystal of sodium thiosulphate in order to neutralise any chlorine, were used for collecting samples for microbiological examination. Separate samples, without thiosulphate were taken for the determination of chlorine levels.

Fig. 1. Air sampling equipment. Left-hand-side shows three air samplers shielded by a pitched steel sheet. Right-hand-side shows two rows of agar plates (settle plates), one row directly below carcasses to detect organisms in drips and one not below carcasses to detect organisms in deflected water droplets.

2.3.2. Sample processing

Water samples were examined without further processing. Organisms from swabs were suspended by agitation using a vortex mixer for ca. 30 s. Skin samples were weighed and then homogenised for 1 min in 50 ml MRD using a stomacher (Seward, London). Decimal dilutions were prepared in MRD and appropriate dilutions surface-plated on the media described below. Each dilution was plated in duplicate. The lower limit of detection was approximately 10 cfu per g for skin, 0.5 cfu per cm^2 for body cavity and environment samples and 2.5 cfu per ml for water and carcass-rinse samples.

2.3.3. Media, microbial groups studied

Aerobic mesophilic microbes were determined using Oxoid Plate Count Agar incubated aerobically at 30°C for 48 h. Presumptive coliforms were detected on Oxoid MacConkey No.3 Agar incubated aerobically for 24 h. Only pink/red colonies >2 mm diameter were counted. A resuscitation method (Anderson and Baird-Parker, 1975) was initially carried out in parallel, but was discontinued when no benefit was found. Presumptive *Pseudomonas* spp. were enumerated on Oxoid cephaloridine–fucidin–cetrimide agar incubated aerobically at 25°C for 48 h. The dilution fluid was Oxoid Maximum Recovery Diluent (MRD).

2.4. Experimental design, presentation and analysis of results

The investigations were of balanced design. For the commercial chillers, each survey was carried out on three occasions using three samples at each site. When using the rig each trial was carried out three times and on each sampling occasion three carcasses were monitored. In order to allow for variations in

the initial microbial load due to prechill processes or flock differences, the results for carcasses were reported as the proportional $\log_{10}$ change from counts obtained prior to chilling. The values, therefore, could be positive or negative depending on whether carcass counts increased or decreased during the chilling process (see tables and figures). Analysis of variance (ANOVA) was undertaken using 'Minitab' software.

Table 2
The mean temperature (°C) of the carcasses during the chilling process

Percentage	Chilling system code[a]					
of process	A	B	C	D	E	F
Surface temperature						
0%	30.1	27.2	24.9	23.3	24.6	25.1
25%	21.4	1.3	13.8	16.7	14.9	16.9
50%	14.6	0.7	7.1	2.3	7.0	7.7
75%	10	NT	3.3	1.9	7.0	7.4
100%	7	1.5	3.1	3.4	5.1	5.9
Deep tissue temperature						
0%	39.6	39.2	38.3	39.6	35.1	35.1
25%	33.7	3.3	23.7	31.3	21.9	27.3
50%	23.6	2.1	12.1	6.7	10.3	13.8
75%	17.2	NT	6.4	4.7	10.5	11.4
100%	12.8	0.4	4.4	3.0	5.7	7

[a] $n=9$ (see Table 1 for details); NT, Not tested; 75% processing point could not be accessed due to safety regulations.

3. Results

3.1. Evaluation of the temperatures and microbial counts from carcasses and environmental samples during commercial chilling

3.1.1. Water chilling

The temperatures following water chilling were 12.8°C, 7.0°C and 5.1°C for deep tissue, carcass surface and water respectively (see Table 2). The numbers of coliforms on carcasses were reduced progressively throughout the process (mean proportional change of $\log_{10}$ – 1.28/body cavity and – 1.10/g neck skin). In the case of pseudomonads, there was an overall reduction in numbers by the end of the process ($\log_{10}$0.05 cfu/g for neck skin and 0.32/body cavity), but was an increase on the neck skins at the beginning of the process (mean $\log_{10}$0.75 cfu/g, see Fig. 2). There was a progressive reduction in microbial numbers with processing time and this was significant for all three categories of organisms

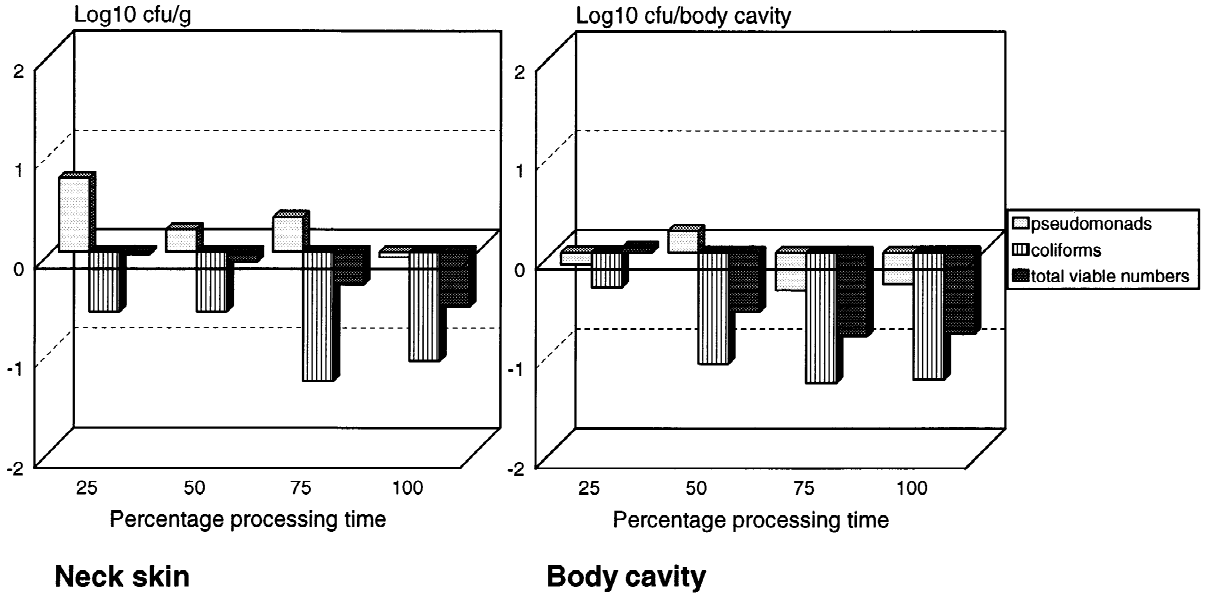

Fig. 2. The mean proportional change in microbial numbers recovered from carcasses during water chilling ($n=9$). (Table 1 – chilling system code A).

($p<0.001$). No coliforms were isolated from the water except at the point where the carcasses entered and the water left the system. There was a significant difference ($p<0.01$) between the levels of total chlorine and free available chlorine at each of the sampling points, 32 ppm/18 ppm, 44 ppm/10 ppm, 42 ppm/9 ppm, 50 ppm/30 ppm and 18 ppm/6 ppm respectively at bird entry, 25%, 50%, 75% and bird exit positions. The level was reduced to 20 ppm at the inlet (100%) point to enable personnel to handle the carcasses without discomfort. The total and free available chlorine levels were highest at the 75% point, close to a chlorine injection point where TVC from the water was extremely low ($\log_{10}$ cfu/ml 0.4).

3.1.2. Air chilling

The rate at which carcass temperatures were reduced varied according to chiller design e.g. the presence of a prechill section (see Table 2). The lowest mean temperature in deep tissue at the end of chilling was found in the spiral Ventstream chiller B (0.4°C) and the highest in the dry Ventstream chiller F, (7.4°C). The chillers with a prechill section (D and E) showed a two-stage temperature profile, with the largest reduction occurring after the prechiller. The clipbar chiller (C) and the two Ventstreams (B and F) with no prechill section showed a steady, progressive drop in temperature. Skin temperatures followed a similar pattern, except that, as would be expected, they declined more rapidly than those found in the deep muscle. Final skin temperatures were usually 1–2°C lower than the deep tissue temperature (see Table 2) except in Chillers D and E where carcasses returned through the prechill section at the end of the chilling process, and in the spiral Ventstream chiller (B), where carcasses at exit could only be sampled outside the chiller. The temperature of the air blowing over the carcasses from the Ventstream ducts was relatively constant throughout the room at −2 to −3°C, while the prechill sections remained at between 7 and 8°C.

Microbial counts from neck skin samples showed very little change. This was confirmed by an ANOVA ($n=1026$) which indicated no significant influence of chiller or sampling site ($p>0.05$). In Chillers C (Fig. 4) and D there was an indication, not confirmed by ANOVA, that counts of all microbial groups were marginally higher immediately after the sprays.

A completely different situation was apparent with the body cavities. The use of water was directly

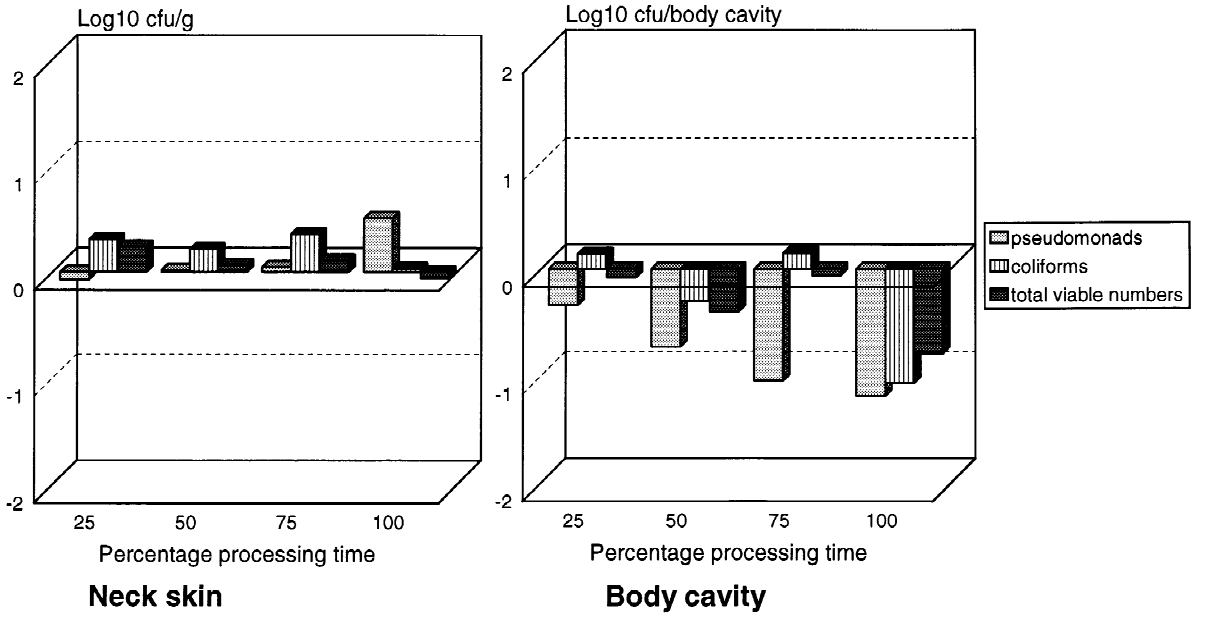

Fig. 3. The mean proportional change in microbial numbers on carcasses during air chilling (dry Ventstream) ($n=9$). (Table 1 – chilling system code F).

Table 3
The mean proportional change in microbial counts recovered from the body cavity following chilling; ($\log_{10}$ cfu/cavity)

	Chilling system code[a]					
	A	B	C	D	B	F
Total viable count	0.82	0.58	0.43	0.49	0.51	1.07
Coliforms	1.28	0.07	0.51	0.51	0.15	1.07
Pseudomonads	0.32	0.42	0.11	0.65	0.98	1.19

[a] $n=9$. See Table 1 for details.

linked to the microbial counts obtained at the end of the process (Table 3). When no water sprays were used (Chiller F) TVC, coliforms and pseudomonads all fell by approximately one unit/body cavity by the end of the process (Fig. 3). In Chiller B, where sprays were applied sparingly in spray cabinets, the corresponding reduction in TVC and pseudomonads was approximately $\log_{10}0.5$. With the use of moderate water sprays, TVC and the counts of coliforms both increased by approximately $\log_{10}0.5$, while the use of relatively heavy, non-chlorinated sprays was associated with an increase of 1-2 $\log_{10}$ units in pseudomonads (Fig. 5). With regard to stage of chilling, mean counts increased between carcass entry and the 25% point (normally the area of the water sprays and wettest carcasses), and then decreased progressively until the 75% stage, after which little further change occurred.

3.1.2.1. Microbial numbers recovered from the air and on 'settle plates'

3.1.2.1.1. *Air samples* Very low counts were obtained with the air samplers. Mean TVC (cfu/m^3) for each chiller ranged from 1.9 to 2.8, i.e. <1 cfu and 6 cfu per 10 l of air, for the chiller without water sprays and the chiller with relatively heavy water sprays respectively. Counts increased in proportion to water usage in the chilling process. In particular, Chiller E, which used non-chlorinated water, was the only one where moderate numbers of coliforms (mean $\log_{10}$ cfu/m^3 2.7) were detected in the air.

3.1.2.1.2. *Settle plates placed under carcasses* Fluid dripped off the carcasses as they entered the air chillers as a result of passing through the inside/outside washer. Therefore, high counts were recorded on settle plates in the first part of the chilling process, and near the water sprays (mean TVC $\log_{10}$ cfu/m^2/min 3 to >5). By the half-way stage, the dripping had stopped and counts decreased ($\log_{10}$ cfu/m^2/min 2.5 to 3). An exception to this was the last part of the process in Chillers D and E,

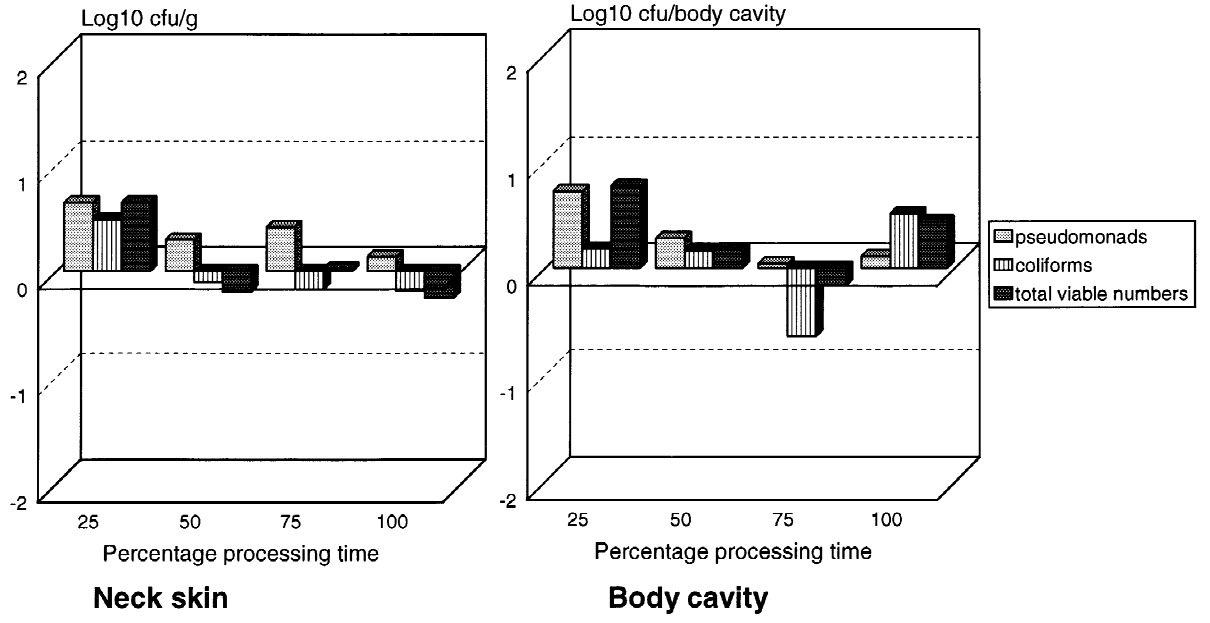

Fig. 4. The mean proportional change in microbial numbers on carcasses during evaporative chilling (Clipbar with moderate chlorinated water sprays) ($n=9$). (Table 1 – chilling system code C).

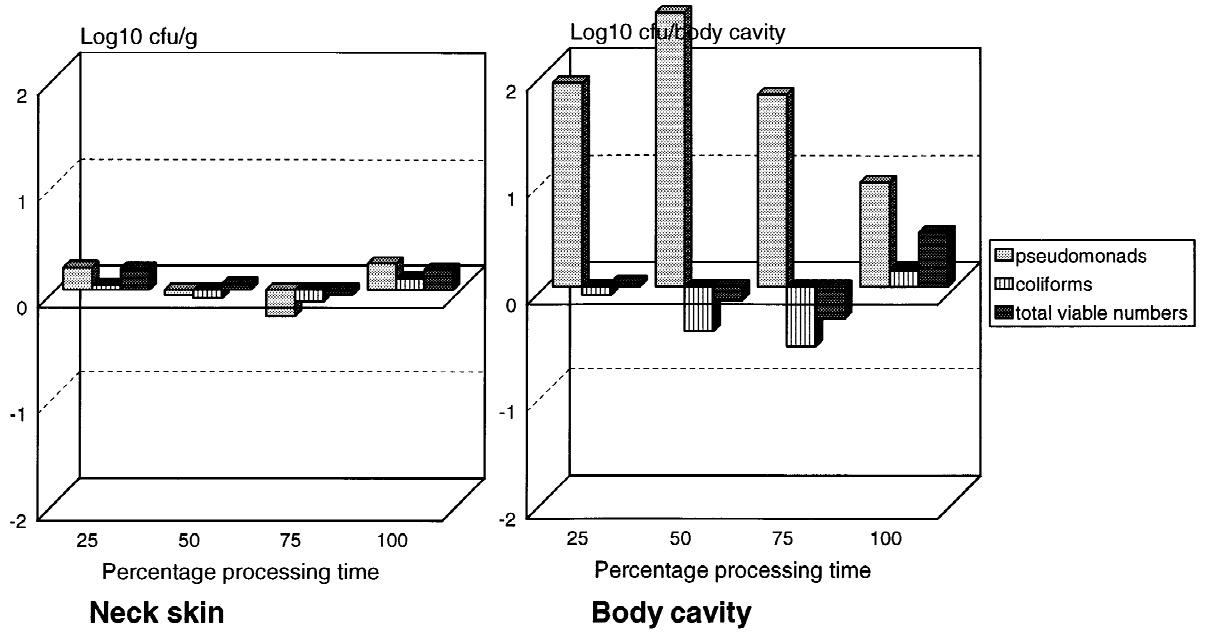

Fig. 5. The mean proportional change in microbial numbers on carcasses during evaporative chilling (Ventstream with relatively heavy unchlorinated water sprays) ($n=9$). (Table 1 – chilling system code E).

where the chilled carcasses passed back through the prechiller near the sprays and close to dripping birds. In Chiller E high numbers of pseudomonads were recovered at the 0%, 25% and 100% points, near the non-chlorinated water sprays.

3.1.2.1.3. *Settle plates placed between rows of carcasses* In the dry chiller (F) the numbers of colonies observed on these plates were uniformly very low, except at the start of the chilling process. Even there numbers were only about 1% of those on the plates placed beneath the rows. In Chiller E, with relatively heavy water sprays, numbers of colonies were similar on both sets of plates. This indicates that microbes were being dispersed, or the drips deflected, by the water sprays.

3.1.2.1.4. *Environmental samples* The mean numbers of microorganisms recovered from the clipbars (Chiller C) and shackles in the Ventstream system (Chiller D) were similar at approx. $\log_{10}$ cfu/cm^2 4.5 and 2.5 for TVC and pseudomonads respectively. No coliforms were isolated (minimum level of detection 0.3 cfu/cm^2). Swabs taken from the floors of the Ventstream chillers B and D (after overnight storage) near the entry point and water sprays, yielded high numbers of pseudomonads and low numbers of coliforms (mean $\log_{10}$ cfu/cm^2 5.7 and 1.7 respectively). In all samples of water taken from the spray outlets, TVC was less than one $\log_{10}$ a cfu/ml, while coliforms and pseudomonads were not isolated (detection level $\log_{10}$ 0.4 cfu/ml).

4. Discussion

4.1. Water chilling

This study confirmed claims made in the literature (Mead, 1989) that water chilling, in a controlled system, as used in the EU (Statutory Instruments, 1995), reduces the microbiological load of carcasses. The detailed investigations reported here also showed that whereas water chilling reduced coliform counts on the skin and in the body cavity of the carcasses, pseudomonads were deposited on the skin in the first part of the process, but were subsequently washed off. There were very few organisms present in the chill water beyond the point of entry of the carcasses, since it was chlorinated at a total residual of 45 mg/l. Since pseudomonads are more resistant than coliforms to chlorine, this would have favoured

their survival both on the carcass and in the water at the entry point where the total residue chlorine level was approximately 30 ppm.

4.2. Air chilling

Modern air chilling processes had very little effect on the microbial numbers recovered from the skin, irrespective of chiller design. These findings were similar to those of Stephan and Fehlhaber (1994) when using a comparable (maceration) technique to examine skin. With the dry Ventstream chiller (F), however, counts of pseudomonads and coliforms from the body cavity showed a clear reduction. This was probably due to the washing effect of water draining out of the body cavity during chilling. In the chillers with sprays, pools of moisture were likely to remain in the cavity. With chlorinated water sprays, used sparingly, microbial counts from the body cavity remained virtually unchanged. Copious spraying with non-chlorinated water (Chiller E) resulted in large increases in pseudomonads (but not other organisms) in the body cavity. The application of super-chlorinated water in poultry processing and its advantages have been reviewed by Mead (1989). While having little or no direct effect on microbial contamination of carcasses, because of rapid inactivation, chlorine is nevertheless an effective agent for controlling microorganisms in the processing environment and hence its use for this purpose by processors in the UK and certain other countries.

Microbial levels in the air were extremely low, although at the beginning of the chilling process they were a little higher, i.e. up to 2 per l of air. It appears, therefore, that very few organisms were being transmitted as particles or aerosols by the air currents. On the other hand, there was ample evidence that fluid draining from the carcasses (either from the inside/outside washer, which is used immediately before the chilling process, or as a result of sprays within the chiller) was relatively heavily contaminated, thus confirming the observations of Stephan and Fehlhaber (1994). This evidence came from the settle plates. There was no sign that the drainage fluid led to microbial transmission by aerosols. However, the formation of fine droplets as the fluid was dispersed on striking the chiller floor, could have resulted in carcass contamination. It is possible that the water sprays, but not the normal air movement, were sufficient to divert contaminated water droplets onto the settle plates located between rows of carcasses, and hence also to carcasses in the immediate vicinity. Counts from the settle plates were in accordance with this hypothesis. Thus, the use of water sprays would not only result in cross-contamination, but could allow the transfer of organisms to carcasses from the floor and other parts of the processing environment including the shackles, that would be contaminated, particularly with pseudomonads. The settle plates were always placed face up and, although the air samplers were designed to collect aerosols, neither the samplers nor the settle plates were designed to collect droplets travelling in an upward or lateral direction. Sampling for droplets in these directions, although difficult to achieve, would have helped to indicate whether organisms were being carried upwards after striking the floor during spraying, or from the break-up of large droplets. However, upward droplet movement, if it did occur, would be confined to a small area and therefore widespread dispersion from this cause would be unlikely. A study on microbial cross-contamination and dispersal using a marker organism is reported in a further publication by Mead et al. (2000).

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