Studies to determine the critical control points in pork slaughter hazard analysis and critical control point systems


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Received 27 February 2002; received in revised form 6 December 2002; accepted 10 March 2003

Abstract

Aerobic mesophilic counts (AMC), coliform (CC) and coliform resuscitation counts (CRCs) were obtained by swabbing 50 cm² areas at three sites (ham, belly and neck) on pig carcasses, after each of seven stages of the slaughter/dressing process (bleeding, scalding, dehairing, singeing, polishing, evisceration and chilling). In most cases, there were no statistical differences (P>0.05) among the counts derived by these three methods. Reductions in counts at individual sites were observed after scalding (3.5 log₁₀ cfu cm⁻²), and singeing (2.5 log₁₀ cfu cm⁻²). Increases in counts at individual sites were observed after dehairing (2.0 log₁₀ cfu cm⁻²) and polishing (1.5 log₁₀ cfu cm⁻²). The incidence of Salmonella on pig carcasses was also obtained by swabbing the outside surfaces of 100 half carcasses. Information on the incidence of Salmonella in scald tank water (108 samples) was also investigated. Carcass swabs and scald tank water were examined for the presence of Salmonella using standard enrichment methods. Salmonella were detected on 31% of carcasses immediately after bleeding, 7% of carcasses immediately after dehairing and evisceration, and 1% of carcasses immediately after scalding. Serovars included Salmonella Typhimurium, Salmonella Hadar, Salmonella Infantis and Salmonella Derby. No Salmonella were recovered from samples of scald tank water. The impact of pig slaughter/dressing processes on carcass microbiology and their potential use as critical control points (CCPs) during pork production are discussed.

Keywords: Pork slaughter; HACCP; Salmonella; Critical control points

1. Introduction

Pork production within the European Community was governed by the 1995 amendment to the Fresh Meat Directive (95/23/EEC), which did not specifically require the application of HACCP-based systems. However, in June 2001, this directive was amended by the Commission Decision and transposed into Irish law. The document now clearly mandates full HACCP systems within pork and other meat processing activities, with meat plants given 12 months in which to achieve compliance. Such HACCP-based methods, involving a systematic, sci-
Scientific approach to process control, designed to prevent, reduce or eliminate identified hazards in food products (Kukay et al., 1996), are generally accepted as the most effective means of minimising the levels of contamination on many food products. However, effective HACCP systems must be based on accurate baseline data on the types and levels of contamination at each stage of production (Gill et al., 1995a), and adequate evaluation of the risks to food safety and/or quality posed by each element of the production process (Gill and Jones, 1997). They also employ accurate baseline data in the ongoing establishment of appropriate critical limits, as means of monitoring the effectiveness of developed control measures. While it is possible to apply a generic HACCP plan to pork slaughter processes, slaughter plants differ, in terms of the range and levels of contamination present. It would therefore be beneficial for each slaughter facility to establish its own baseline reference data, and customise available generic HACCP plans to match site specific circumstances and processes (Vanne et al., 1996).

Current levels of occurrence of a number of pathogens, including Salmonella, pose potential threats to consumers and, in the longer term, to the viability of the pork processing industry. For example, surveys of retail outlets in Ireland have found pork products to be contaminated with Listeria (45%, Sheridan et al., 1994) Yersinia (100%, Logue et al., 1996), and Salmonella (9.9%, Duffy et al., 1999). These reports are generally in line with data from other countries that confirm the significance of pork as an important source of foodborne pathogens. For example, the average incidence of salmonellosis in the Netherlands is about 100,000 cases per year, with an estimated 15% of these being associated with pork consumption (Berends, 1998). Similarly Wegener et al. (1997) reported that contaminated pork was estimated to account for 10% to 15% of outbreaks of salmonellosis in humans in Denmark. The dangers posed by the consumption of contaminated pork have been highlighted by at least two major pork-associated outbreaks of salmonellosis in Denmark within the last 10 years. In 1993, an outbreak in Copenhagen resulted in 550 people becoming ill (Bager et al., 1995), while an outbreak of multi-resistant Salmonella typhimurium DT104 in 1998 resulted in 25 culture-confirmed cases and 2 deaths (Baggesen et al., 1999). In both outbreaks, contamination was traced back to local pork abattoirs. In addition to such direct human costs in terms of illness and suffering, the association of food poisoning outbreaks with pork products has major economic impacts on the pork processing industry. Thus, the Economic Research Service (ERS) of the United States Department of Agriculture (USDA) estimate that food-borne Salmonella infections associated with pork products in the US cost $0.1 to 0.2 billion per year (Frenzen et al., 1999).

The primary objectives of this study were to provide baseline data on the types and levels of bacterial contamination on carcasses, to identify potential CCPs during pork slaughter, and to investigate the effects of the main steps of the slaughter/dressing process on the prevalence of Salmonella during pork production.

2. Materials and methods

2.1. Slaughter plant and process

Samples were drawn from a plant processing approximately 1000 locally sourced pigs per day. Animals were held in lairage, stunned using carbon dioxide, transferred into the “wet” room, and immediately exsanguinated by severing of the carotid arteries and jugular vein. Exsanguinated animals were scalded for approximately 8 min using a linear “scald tank” (61 ± 1 °C). Scalded carcasses were dehaired using a rotating drum with scrapers that flailed the carcass surface, dislodging hair and skin debris. Dehaired carcasses were secured to an overhead conveyor rail by insertion of a gambrel hook into the hind leg tendons. Carcasses were then passed through a singer operating at approximately 1200 °C for 15 s. Singed carcasses were polished by passage through a series of horizontal and vertical flails in a process that lasted approximately 5 min.

Polished carcasses were moved into a separate evisceration area. Carcasses were “debugged” by cutting around the rectum with a knife, which had been immersed in water heated to 82 °C before use. The detached rectum was sealed with a plastic bag to prevent faecal contamination of carcasses during subsequent processing. The belly was opened, and the diaphragm, heart, lungs, trachea, and the digestive
tract, were removed. Carcasses were manually split along the midline, from the hind to the fore using a splitting saw, the heads were removed, and the spinal cord excised. Carcasses were then trimmed, weighed and graded, before spray washing for approximately 10 s with cold potable water containing between 0.8 and 1.2 ppm chlorine (to remove bone dust and blood clots). Washed carcasses were chilled to between 2 and 4 °C overnight.

2.2. Sampling plan

This study was conducted over eight visits to a pork processing plant. Carcasses were examined at three sites (ham, belly and neck) after seven process stages (Table 1). Due to logistical constraints, it was not possible to sample the same carcass at every process stage on the same day. As a result on a given day, a number of specific stages were selected for sampling e.g. on day 1, bleeding, scalding and dehairing stages were examined. On a subsequent day, dehairing, singeing, and polishing stages were sampled, i.e. an overlap in sampling took place at the dehairing stage. This sampling regime was continued until all seven stages had been examined. As a result, the number of carcasses sampled at each process stage was as follows: bleeding (24), scalding (24), dehairing (53), singeing (29), polishing (48), evisceration (20) and chilling (20).

2.3. Estimation of bacterial numbers on carcasses

Sterile cellulose sponges (100 × 100 × 10 mm³) (Sydney Heath & Son, Staffordshire, England) were prepared in sterile stomacher bags, and moistened with Maximum Recovery Diluent (MRD, Oxoid). Immediately prior to use each sponge was grasped through the sterile plastic bag, which was inverted to present the sample sponge. A separate sponge was used to swab a 50-cm² area of the ham, belly or neck of each carcass (Table 1). After swabbing, the sponge was withdrawn into the stomacher bag and stomached with 100 ml MRD in a Colworth Stomacher (Model BA 6024, A.J. Steward and Company, London, UK). Serial dilutions of the resultant bacterial suspension were prepared and plated; (1) onto Plate Count Agar (PCA, Oxoid), which was incubated at 25 °C for 48 h; (2) onto MacConkey agar (Oxoid), which was incubated at 37 °C for 48 h; (3) onto Tryptic Soya Agar (TSA, Oxoid), which was incubated at 37 °C for 2 h, over-poured with MacConkey agar and incubated at 37 °C for a further 48 h. These procedures provided, aerobic mesophilic counts (AMC), coliform counts (CCs) and coliform resuscitation counts (CRCs), respectively.

2.4. Detection of Salmonella on carcasses and in scald tank water

In a more specific element of the study, 100 pork carcasses and scald tank water used in their treatment were examined for the presence of Salmonella using ISO standard methods (ISO, 1981). Carcasses were tagged and tracked through the dressing process. At each sample stage, the entire outside surface of each tagged half carcass was swabbed using an individual swab prepared as previously described (Lasta et al., 1992). Swabs were then stomached with 100 ml of buffered peptone water (BPW, Oxoid) for 1 min and incubated at 37 °C for 24 h. After incubation, a 0.1-ml aliquot of the enriched culture was transferred into 10 ml of Rappaport Vassiliadis (RV) medium (Oxoid) and incubated at 42 °C for a further 24 h.

A total of 108 (100 ml) samples of the scald tank water were taken at 18, evenly spaced locations along the scald tank, including samples from the top, middle and bottom of the tank. Each sample was supple-

Table 1

<table>
<thead>
<tr>
<th>Location</th>
<th>Process stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet room</td>
<td>Lairage</td>
</tr>
<tr>
<td></td>
<td>Stunning</td>
</tr>
<tr>
<td></td>
<td>Bleeding*</td>
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<tr>
<td></td>
<td>Scalding*</td>
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<tr>
<td></td>
<td>Dehairing*</td>
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<tr>
<td></td>
<td>Singeing*</td>
</tr>
<tr>
<td></td>
<td>Polishing*</td>
</tr>
<tr>
<td></td>
<td>Debunging</td>
</tr>
<tr>
<td></td>
<td>Carcass opening</td>
</tr>
<tr>
<td></td>
<td>Evisceration*</td>
</tr>
<tr>
<td></td>
<td>Carcass splitting</td>
</tr>
<tr>
<td></td>
<td>Trimming</td>
</tr>
<tr>
<td></td>
<td>Stamping</td>
</tr>
<tr>
<td></td>
<td>Final washing</td>
</tr>
<tr>
<td>Chiller</td>
<td>Chilling*</td>
</tr>
</tbody>
</table>

*Process stages surveyed for bacterial counts.
mented with 100 ml of double strength BPW and incubated at 37 °C for 24 h. After incubation, a 0.1-ml aliquot of each enriched culture was transferred into 10 ml of RV medium and incubated at 42 °C for a further 24 h.

Enrichment cultures from swabs and from scald tank water were streaked out onto Brilliant Green Agar (BGA, Oxoid), incubated at 37 °C for 24 h, and examined for red colonies (presumptive Salmonella). The enrichment cultures were also streaked out onto Mannitol Lysine Crystal Violet Brilliant Green (MLCB, Oxoid) Agar, incubated at 37 °C for 24 h, and examined for large black colonies (presumptive Salmonella). Both types of presumptive Salmonella were recovered, purified and cultured on non-selective media (TSA, Oxoid) at 37 °C.

2.5. Confirmation and speciation of Salmonella

Presumptive Salmonella colonies were identified to genus level. Biochemical tests included the Gram reaction, the Kohns two-tube test (Mast Diagnostics, Merseyside, UK; fermentation of dextrose, mannitol and sucrose/salicin; production of urease, motility, hydrogen sulphide and indole, the lysine decarboxylase test (Oxoid) and β-galactosidase activity (ONPG discs, Oxoid). Colonies exhibiting the biochemical profile of Salmonella spp. (motile, positive for dextrose, mannitol and lysine decarboxylase, negative for urease, sucrose/salicin, ONPG, indole and the production of hydrogen sulphide) were maintained on TSA slopes at 2 °C and subjected to serological analysis by latex agglutination tests (Murex, Kent, UK) for cell-associated Salmonella O antigens and polyvalent O and H slide agglutinations (Murex). Confirmed colonies were maintained on TSA slopes and speciated at the Central Veterinary Research Laboratory, Abbots-town, Castleknock, Dublin by slide agglutination analysis using species-specific Salmonella O and H antigens (Kauffmann, 1966).

2.6. Scald tank temperature measurement

The temperature of the scald tank water was continuously monitored and recorded using two temperature probes and data loggers (± 0.5 °C) positioned at either end of the scald tank (Testo, Lenzkirch, Germany).

2.7. Statistical design and analysis

The aerobic mesophilic counts, coliform and coliform resuscitation counts obtained from the ham, belly and neck regions from each carcass were transformed to log_{10} values. A log value of −0.5 was assumed for samples in which bacterial counts were not detected at the level of 1 cfu per 50 cm². The total viable counts were analysed as a randomised block design with three sites and the individual carcasses as blocks. The coliform and coliform resuscitation counts were also analysed as a randomised block design with the three sites and two media in factorial combination and the individual carcasses as blocks. These analyses were performed using Genstat 5 (Statistics Department, Rothamsted Experimental Station, Hertfordshire, UK). In each analysis, specific comparisons were made using the least significant difference as a guide.

Since the data for the process stages are not independent, a non-parametric test, Kruskal–Wallis was used to analyse the data. This test is based on ranks that are assigned to the data, as an aid to interpreting the results, the mean ranks for the process stages are given in the tables. Comparisons between the individual stages were made using the multiple comparison test (Conover, 1980).

3. Results

The AMC as estimated by sponge swabs taken from the ham, belly and neck areas of carcasses during processing are presented in Table 2. After bleeding, AMCs on the ham, belly and neck were 6.41, 6.35 and 6.13 log_{10} cfu cm⁻², respectively. After scalding, the AMCs from all three areas were significantly (P<0.001) reduced to approximately 2.5 log_{10} cfu cm⁻². After dehairing, AMCs on the ham, belly and neck were approximately 2 log_{10} cfu cm⁻² higher than after scalding. After singeing, AMCs on the ham and belly (2.20 and 2.25 log_{10} cfu cm⁻², respectively) were significantly higher (P<0.01) than AMCs on the neck (1.80 log_{10} cfu cm⁻²). After polishing, AMCs on each area of the carcass were significantly (P<0.001) higher (1.5 log_{10} cfu cm⁻²) than after singeing. While AMCs after evisceration were statistically different from those after polishing, the magnitude of the difference could not be of
practical use. After evisceration, AMCs on the belly area \((3.66 \log_{10} \text{ cfu cm}^{-2})\) were significantly higher \((P < 0.001)\) than on the ham \((3.05 \log_{10} \text{ cfu cm}^{-2})\) or neck \((3.20 \log_{10} \text{ cfu cm}^{-2})\). Significant increases \((P < 0.01)\) were observed on the neck area of the carcass during chilling/chilled storage but not on the ham or belly.

The CCs taken from the ham, belly and neck areas of carcasses during processing are presented in Table 3. After bleeding, CCs on the ham, belly and neck were approximately \(6 \log_{10} \text{ cfu cm}^{-2}\). After scalding, an approximate \(3.5 \log_{10} \text{ cfu cm}^{-2}\) reduction in CCs was observed. Significantly higher \((P < 0.001)\) CCs on the ham, belly and neck were observed after dehairing. After singeing, CCs at the three sample sites were \(1.03, 1.33\) and \(0.84 \log_{10} \text{ cfu cm}^{-2}\), respectively, values approximately \(2–2.5 \log_{10} \text{ cfu cm}^{-2}\) lower \((P < 0.001)\) than after dehairing. After polishing, CCs on the ham, belly and neck areas were approximately \(1.5 \log_{10} \text{ cfu cm}^{-2}\) higher \((P < 0.001)\) than after singeing. After evisceration, CCs on the belly area of the carcass were significantly higher \((P < 0.01)\) than the CCs on the ham or neck. CCs increased significantly \((P < 0.001)\) during chilling/chilled storage on the neck but not on the ham or belly areas of the carcass.

Some significant differences were observed between AMCs and CCs at a number of stages of the process, i.e. CCs were significantly lower \((P < 0.05)\) than AMCs in samples recovered after each of three stages of the process, i.e. dehairing, singeing and polishing.

The CRC taken from the ham, belly and neck areas of carcasses during processing are presented in Table 3. The CRCs were significantly higher \((P < 0.01)\) than the CC after scalding and dehairing.
The presence of *Salmonella* as detected by sponge swabbing the outside surface of half carcasses after each process stage are presented in (Table 4). After bleeding, *Salmonella* were detected on 31% of swabbed carcasses. The isolates were subsequently identified as *S. Typhimurium*, *Salmonella Hadar*, *Salmonella Infantis* or *Salmonella Derby*. Following scalding, *Salmonella* was detected on only 1% of carcasses (*S. derby*). After dehairing, *Salmonella* were detected on 7% of swabbed carcasses (*S. Typhimurium*, *S. Derby*). After singeing and polishing, *Salmonella* were not detected on any carcass. After evisceration, *Salmonella* were recovered from 7% of swabbed carcasses (*S. Typhimurium*). The average temperature of water in the scald tank during carcass processing was 61 °C. *Salmonella* were not detected in any samples of scald tank water.

<table>
<thead>
<tr>
<th>Location</th>
<th>Incidence of <em>Salmonella</em> (%)</th>
<th>Serotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>After bleeding</td>
<td>31</td>
<td><em>S. Hadar</em>, <em>S. Typhimurium</em>,</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>S. Derby</em>, <em>S. Infantis</em></td>
</tr>
<tr>
<td>After scalding</td>
<td>1</td>
<td><em>S. Derby</em></td>
</tr>
<tr>
<td>After dehairing</td>
<td>7</td>
<td><em>S. Typhimurium</em>, <em>S. Derby</em></td>
</tr>
<tr>
<td>After singeing</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>After polishing</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>After evisceration</td>
<td>7</td>
<td><em>S. Typhimurium</em></td>
</tr>
</tbody>
</table>

4. Discussion

One of the most important steps in developing a HACCP system is the establishment of critical control points (CCPs). These are steps at which control can be applied to eliminate, reduce or prevent food safety hazards. In terms of fresh meat processing, safety hazards cannot be eliminated but they can be prevented or reduced (Sheridan, 2000).

In the present study, the AMC, CC and CRCs were approximately 3.7, 3.6 and 3.3 log_{10} cfu cm^{-2} lower after scalding than related counts after bleeding, reductions similar to those reported for pigs by Snijders (1988) and Gerats (1990). Scalding also reduced the incidence of *Salmonella* on carcasses from 31% to 1%.

The present and other studies have shown that scalding reduces bacterial numbers, and the incidence of pathogens such as *Salmonella*, and should be considered as a CCP within a HACCP system. This study also noted that CRCs were significantly higher than the CCs after scalding, indicating that bacteria on carcasses are stress damaged during scalding. This finding is similar to that of another study conducted by Yu et al. (1999), suggesting that the use of resuscitation techniques is essential to avoid an underestimation of bacterial numbers on carcasses at this stage.

During this study, AMC were significantly higher after dehairing (2 log_{10} cfu cm^{-2}) than after scalding and an increase in *Salmonella* positive carcasses from 1% to 7% was also observed. These findings and those of several other studies (Morgan and Krautil, 1989; Gill and Bryant, 1993; Gill and Jones, 1995; Davies et al., 1999) confirm dehairing as a major source of carcass contamination.

Using an automated singeing system resulted in a 2.5 log_{10} cfu cm^{-2} reduction in AMC, CC and CRCs, which are in agreement with Troeger (1993) for total bacterial counts. The significantly lower counts on the neck, compared to the ham and belly, may be related to the singeing system used. In the present study, a single gas flame from the base of the machine was used, resulting in the neck receiving a more severe heat treatment. Where multiple heat source singeing (Yu et al., 1999) was used, such differences between sites were not observed. The data also showed a reduction in the incidence of *Salmonella* from 7% to 0% as a result of singeing. Reductions in *Salmonella* positive carcasses have been recorded elsewhere in the literature (Davies et al., 1999; Berends et al., 1997). If singeing is to be a CCP in future HACCP schemes, it will be necessary to standardise this process, such as the operating temperature, treatment duration, etc. Currently, such parameters are rarely noted or reported.

Increased AMC, CC and CRCs were observed after carcasses had been polished. These increases may be related to the redistribution of residual contamination during polishing (Snijders et al., 1984; Gill et al., 1995b) or from recontamination with debris within the equipment. Despite these increases in counts, *Salmonella* levels remained unchanged.

Evisceration resulted in significant increases in AMC, CC and CRCs. Differences in contamination
were noted on the belly, compared to the ham or neck, an observation also made by Miller et al. (1997). Major changes in the incidence of Salmonella during evisceration occurred with contamination increasing from 0% to 7%. Other researchers have reported similar or larger increases in the incidence of Salmonella during evisceration (Berends et al., 1997; Davies et al., 1999; Hald et al., 1999).

Numerical, but not statistically significant increases, except on the neck in, AMC, CC, and CRCs were observed on carcasses after chilling. In another study, our research group observed a significant increase (P < 0.05) in total counts on pork carcasses after chilling (Bolton et al., 2002), as did Gill and Bryant (1992). Other studies have reported bacterial numbers as increasing, decreasing or remaining static, in response to differences in processing and chilling methods (Gill et al., 2000). Sheridan (2000) stated that chilling rates are influenced by intrinsic factors such as carcass weight, temperature, and fat cover, and extrinsic factors including, chill temperature, air speed, relative humidity and carcass spacing. Factors associated with the resistances of bacteria to chilling and the nature and extent of protection by microniches within carcasses have been reviewed by Borch et al. (1996). Information on chilling parameters will have to be obtained, before the critical limits for carcass chilling can be defined.

In this study, the coliforms were used as faecal indicators in preference to E. coli and Enterobacteriaceae counts which are generally present in very low numbers. Such low counts frequently result in negative log values, making comparisons between treatments statistically difficult. The coliforms, because they represent a more diverse group of organisms, are capable of showing significant differences between treatments. In this investigation, it was important to establish if significant reductions in bacterial counts occurred as a result of different treatments, such as scalding in order to determine if these could be used as CCPs. The use of coliform counts however presents difficulties in relation to determining if carcasses are acceptable within HACCP systems, since the indicators used to determine carcass hygiene are E. coli or the Enterobacteriaceae (Anonymous, 1996, 2001).

In 1996, the United States Food Safety and Inspection Service (FSIS) introduced the pathogen reduction and HACCP systems as a means of controlling food safety hazards in fresh meat processing, including pork (Anonymous, 1996). The objective of this system is that pathogen numbers, in this case Salmonella, will be reduced over time as a result of the introduction of HACCP into meat plants. The performance ‘standards’ for Salmonella are based on data collected before the introduction of HACCP from a nationwide baseline study carried out by FSIS (Anonymous, 1996). In the present study, the level of contamination from Salmonella of 7% at the end of processing would have been within the performance standard set by the FSIS of 8.7% for the presence of this pathogen on pig carcasses.

In addition to Salmonella performance standards, the pathogen reduction programme also uses performance criteria based on E. coli to determine the effectiveness of control of the slaughter process in preventing carcass contamination with faeces. The performance criteria for pigs are based on a three class sampling plan of acceptable 10 (log10 1.0 cfu cm−2), marginal 10–10,000 (log10 1–4 cfu cm−2) and unacceptable < 10,000 (log10 4.0 cfu cm−2). The presence of more than three marginal results within any 13 consecutive samples is considered indicative of an operation failing to meet the criteria and signals a review of the process and corrective action if necessary.

In 2002, the EU introduced a HACCP system for fresh meat slaughter, including pigs (Anonymous, 2001). However, decontamination interventions, such as acid washes, are not permitted, although hot water could be used, and is commonly used in other countries (Gill et al., 1995b, 1997). Interventions such as scalding, singeing and possibly hot water washing and chilling could be used as CCPs in the EU pig HACCP system.

The EU system, like that in the US, has performance criteria, though no pathogen performance standards, to measure the effectiveness of control of the slaughter process through the application of HACCP. It is also based on a three class attributes sampling plan, but the criteria to be measured are the AMCs and the Enterobacteriaceae or E. coli counts. The AMC criteria for pigs are acceptable < log 4.0, marginal log 4–5 and unacceptable > log 5.0. The enteric criteria are acceptable < log 2.0, marginal log 2–3 and unacceptable > log 3.0. In this plan, the bacterial numbers are in log10 A values, which is the
log of the arithmetic mean. These values are calculated from a number of carcasses, used to estimate the mean ($\bar{x}$) and standard deviation ($s$) (Brown et al., 2000). The log $A$ values are calculated from the formula $\log A = \bar{x} + \log_s 10 (S^2/2)$ (Kilsby and Pugh, 1981).

The use of log $A$ values is preferred in these types of comparisons, since it has the advantage of reducing the variability between samples (Hildebrandt and Weiss, 1994). The data for the AMCs in the present study indicated that the slaughter process would have been considered acceptable at the time when visits were made during the determination of the CCPs, with a mean value of 3.46 and standard deviation of 0.46, resulting in log $A$ value of 3.81.

A further difference in the US and EU HACCP plans is the use of the ‘marginal’ data. As stated above the US system stipulates that only three marginal counts are allowed in a set of 13 to signal a process review. The EU HACCP plan is much more vague and states that unsatisfactory marginal result trends should trigger a review of process controls. No indication is given on how many marginal results constitute a ‘trend’.

Unlike the HACCP system in the US, the EU system does not have any ‘standards’ for pathogen reduction. In the US, pathogen performance ‘standards’ are used as a measure of the effectiveness of HACCP to address food safety hazards, which as shown above are based on the incidence of Salmonella contamination on pig carcasses. The relationship between the introduction of HACCP into a meat plant and the reduction in Salmonella is an integral part of the pathogen reduction programme (Anonymous, 1996).

This study provided information on the effectiveness of scalding and singeing in reducing the numbers of Salmonella, coliforms and AMCs on pig carcasses in a slaughter plant in Ireland. The information obtained indicates that this plant would meet some of the EU performance criteria and the US standards for Salmonella. In drawing comparisons between the two HACCP systems, it is clear that the US pathogen reduction programme, in addition to verifying process control, is also focussed on reducing the incidence of pathogens. The EU system at present requires just hygiene standards to verify process control and lacks the food safety element, a situation that should be addressed. For HACCP to operate to its full potential and to improve food safety and reduce the risk of foodborne illness, general hygiene standards alone are not sufficient.

Acknowledgements

The authors wish to acknowledge John Egan of the Central Veterinary Research Laboratory, Abbotstown, Castleknock, Dublin, for serological identification of the Salmonella isolates. This work has been funded by the United States/Ireland Co-operation Programme in Agriculture Science and Technology.

References


Davies, R.H., McLaren, I.M., Bedford, S., 1999. Distribution of 
Salmonella contamination in two pig abattoirs. Proceedings of 
the 3rd International Symposium on the Epidemiology and Con-

Duffy, G., Cloak, O.M., O’Sullivan, M.G., Guillet, A., Sheridan, 
J.J., Blair, I.S., McDowell, D.A., 1999. The incidence and antibi-
totic resistance profiles of Salmonella spp. on Irish retail

of the economic costs of human illness due to foodborne Sal-
monella in the United States. Proceedings of the 3rd Interna-
tional Symposium on the Epidemiology and Control of 

control and hygiene in the meat industry. Thesis, Utrecht Uni-
versity, Utrecht, The Netherlands.

Gill, C.O., Bryant, J., 1992. The contamination of pork with spoil-
age bacteria during commercial dressing, chilling and cutting of 
pig carcasses. International Journal of Food Microbiology 16, 
51–62.

Gill, C.O., Bryant, J., 1993. The presence of Escherichia coli, 
Salmonella and Campylobacter in pig carcass dehairing equip-
ment. Food Microbiology 10, 337–344.

and Yersinia in carcass processing equipment at two pig slaugh-
tering plants. Food Microbiology 12, 135–141.

Gill, C.O., Jones, T., 1997. Assessment of the hygienic character-
istics of a process for dressing pasteurized pig carcasses. Food 
Microbiology 14, 81–91.

hygienic characteristics of a beef carcass dressing process. Jour-
nal of Food Protection 59 (2), 136–140.

Gill, C.O., McGinnis, D.S., Bryant, J., Chabot, B., 1995b. Decon-
tamination of commercial, polished pig carcasses with hot water. 
Food Microbiology 12, 143–149.

Gill, C.O., Bedard, D., Jones, T., 1997. The decontamination per-
formance of a commercial apparatus for pasteurizing polished 
pig carcasses. Food Microbiology 14, 71–79.

Gill, C.O., Dussault, F., Holley, R.A., Houde, A., Jones, T., Rhetaut, 
performances of the processes for cleaning, dressing, and cool-
ing pig carcasses at eight packing plants. International Journal of 
Food Microbiology 58, 65–72.

Hald, T., Wingstrand, A., Swanenberg, M., Altrock, A.V., Limpi-andis, N., Thorberg, B.M., 1999. Harvest epidemiology of Salm-
onella contamination in EU pig slaughterhouses. Proceedings of 
the 3rd International Symposium on the Epidemiology and Con-

Hildebrandt, G., Weiss, H., 1994. Sampling plans in microbiologi-
ical quality control: 2. Review and future prospects. Fleischwirt-
schaft International 74 (2), 165–168.

ISO, 1981. International organisation for Standardisation 6579. Mi-
crobiology General Guidance on Methods for the Detection of 
Salmonella. International Organisation for Standardisation ISO, 
Geneva, Switzerland.

Kauffmann, F., 1966. The Bacteriology of Enterobacteriaceae: III. 
Salmonella. Munksgaard-Copenhagen, Copenhagen, Denmark, 
pp. 69–147.

Kilsby, D.C., Pugh, M.E., 1981. The relevance of the distribution of 
micro-organisms within batches of food to the control of micro-
biological hazards from foods. Journal of Applied Bacteriology 
51, 345–354.

Kukay, C.C., Holcomb, L.H., Sofos, J.N., Morgan, J.B., Tatsum, 
by small-scale and medium-scale meat processors. Dairy, Food 
and Environmental Sanitation 16 (2), 74–80.

terial count from bovine carcasses as an indicator of hygiene at 

Logue, C.M., Sheridan, J.J., Wauters, G., McDowell, D.A., Blair, 
I.S., 1996. Yersinia spp. and numbers, with particular reference to 
Y. enterocolitica bio/serotypes, occurring on Irish meat and fish 
products, and the influence of alkali treatment on their isolation. International Journal of Food Microbiology 33, 
257–274.

Miller, M.F., Carr, M.A., Bawconry, D.W., Ramsey, C.B., Thompson, 
L.D., 1997. Microbiology of pork carcasses from pigs with dif-
fering origins and feed withdrawal times. Journal of Food Protection 60 (3), 242–245.

Morgan, I.R., Krautil, F.L., 1989. Microbiological contamination of 
pig carcasses. Proceedings of the Bennial Conference of the 
Australasian Pig Science Association. Australasian Pig Science 
Association, Victoria, pp. 38–45.

Brown, M. (Ed.), HACCP in the Meat Industry. CRC Press, 

ocurrence and initial numbers of Listeria in Irish meat and fish 
products and the recovery of injured cells from frozen products. 

Fleischwirtschaft 68 (6), 753–756.

manufacturing practices during slaughtering. Archiv fur Lebens-

Troeger, K., 1993. Scalding and dehairing technology. Influence on 
the bacterial count of pig carcasses. Fleischwirtschaft 73 (10), 
1157–1160.

HACCP-based quality control and rapid detection methods for 

Wegener, H.C., Bagesen, D.L., Gerner-Smidt, P., 1997. Epidemi-
ology of Salmonella and salmonellosis in Denmark. Proceedings 
of Salmonella and Salmonellosis, 21–22 May, Ploufragan, 
France, pp. 551–554.

Yu, S.-L., Bolton, D., Laubach, C., Kline, P., Oser, A., Palumbo, 
S.A., 1999. Effect of dehairing operations on microbiological 
quality of swine carcasses. Journal of Food Protection 62 (12), 
1478–1481.