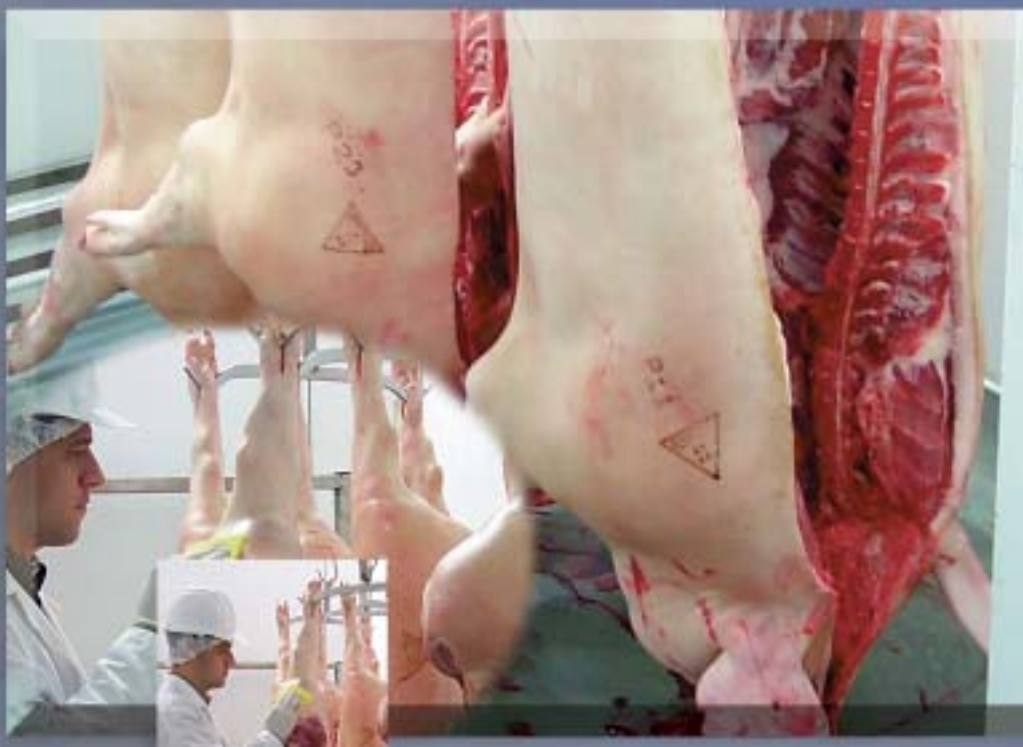
FINAL REPORT

Project RMIS No.4667

Risk-based Determination of Critical Control Points for Pork Slaughter



The National Food Centre

RESEARCH & TRAINING FOR THE FOOD INDUSTRY

RESEARCH REPORT NO 56

Contents

RISK BASED DETERMINATION OF CRITICAL CONTROL POINTS FOR PORK SLAUGHTER

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SUMMARY

To identify the critical control points (CCPs) during commercial pork slaughter, 60 pigs in a small abattoir (80 pigs per day) and a similar number in a larger plant (2000 pigs per day) and/or their resultant carcasses were swabbed at the ham, belly and neck. The total bacterial contamination was determined after each stage from the live pigs on the farm to chilling of the carcasses in the abattoir.

Pre-slaughter washing of the live animals did not reduce total bacterial count. Carcass dehairing and polishing increased contamination while scalding and singeing had the opposite effect. Powerhosing with cold water instead of passage through the polishers also increased bacterial number on the carcasses.

In the small plant, *Salmonella* was found on 27% of pigs, which decreased to 10% after pre-slaughter powerhosing. Bleeding caused an increase in *Salmonella* to 50% of all carcasses. *Salmonella* was completely eliminated by scalding. In the larger plant, scalding reduced *Salmonella* contamination from 31% to 1% of all carcasses.

In the large plant, airborne bacteria increased from 1.6 to 2.5 $\log_{10}$ cfu m^{-3} up to a maximal count of 3.6 $\log_{10}$ cfu m^{-3} throughout the days' production. This included *Salmonella Typhimurium*, which was detected in the air on two occasions at dehairing and once at evisceration. There was a strong correlation between the airborne bacterial count as detected using air samplers and using settle plates.

Cross contamination of the carcasses from the dehairing and polishing machines and from the environment are most effectively controlled through the implementation of good manufacturing practices (GMP) while scalding, singeing, evisceration and chilling may be used as CCPs in a pork slaughter HACCP plan.

INTRODUCTION

While accurate food poisoning statistics are unavailable for Ireland, pork has been confirmed as a vehicle of pathogen transmission in several other countries. Salmonellosis in the Netherlands, for example, is about 450 per

100,000 of the population, with an estimated 15% of these being associated with pork consumption (Berends *et al.*, 1998). The corresponding figure in Denmark is 95 cases per 100,000 with 10-15% attributed to pork consumption (Hald and Wegener, 1999). Pork is the second highest food source of this pathogen in Denmark, surpassed only by eggs. Indeed, in the recent past, the Danes have suffered at least 2 major *Salmonella* outbreaks associated with pork. In 1993, an outbreak in Copenhagen resulted in 550 people becoming ill (Bager *et al.*, 1995). In June, 1998, an outbreak of antibiotic-resistant *Salmonella Typhimurium* DT104 resulted in 25 culture-confirmed cases and 2 deaths (Baggesen *et al.*, 1999). The source of infection was traced back to a local pork abattoir.

While pork processing plants cannot guarantee that their product will always be free of bacterial pathogens, ever effort must be made to decrease the incidence of pathogens and therefore reduce the ultimate risk to the consumer. At present, hazard analysis and critical control point (HACCP) is generally regarded as the most effective means of achieving this during pork slaughter and thus has been legally mandated in the United States of America since 1996 and will be required within the EU after the 8th June 2002 (Anon, 2001).

HACCP development requires scientific data which identifies and quantifies the hazards that may occur during a given food process. Hither-to-fore this data was unavailable for Irish pork slaughter. While previous studies identified some of the hazards associated with Irish pork at retail (Cloak, 1999; Logue, 1996; Sheridan et al, 1994), research was needed at each step in the slaughter process to determine where product contamination or decontamination occurs.

This research provides data for the development of Irish pork slaughter HACCP. Baseline studies were undertaken in a large Irish commercial pork slaughter operation (approximately 2000 pigs per day) and a small slaughter house (80 pigs per day) in the south-east, with the aims of determining the incidence and total viable counts (TVC) of bacteria, total enteric counts (TEC) and *Salmonella* on the live animals and on their carcasses at every stage during slaughter and in the slaughter environment. The main results are now presented with particular emphasis on their function in HACCP development.

BASELINE STUDIES IN A SMALL IRISH COMMERCIAL PORK PLANT

The ham, belly and neck of the carcasses were swabbed after each stage from the farm to chilling in the abattoir. The counts on the ham, belly and neck at each stage during slaughter are shown in Figure 1.

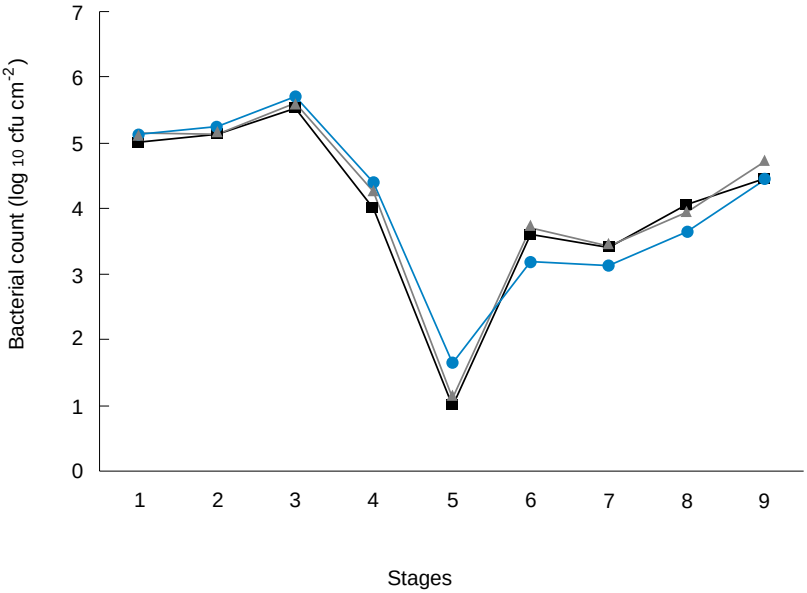

Figure 1: Bacterial contamination of pork carcasses in a small plant. Total bacterial counts (log_{10} cfu cm^{-2}) on pork carcasses at the ham (■), belly (●) and neck (▲); (1) on the farm and after (2) washing; (3) bleeding; (4) dehairing; (5) singeing; (6) powerhosing; (7) evisceration; (8) washing; and (9) chilling.

The bacterial levels on the live animals immediately before loading and transport to the abattoir were approximately 5 log_{10} cfu cm^{-2} (Figure 1). *Salmonella Agona* were isolated from the skin of 27% of these animals (Table 1). Powerhosing produced a visibly clean pig. However, the total bacterial counts remained at approximately 5 log_{10} cfu cm^{-2}, although the incidence of *Salmonella* decreased to 10%.

Table 1: Incidence of *Salmonella* on pigs and pig carcasses at different stages during slaughter in a small plant

Process stage	*Salmonella* positive	Serotypes
1. Before transport	27%	S. Agona
2. After powerhosing	10%	S. Agona, S.Typhimurium
3. After bleeding	50%	S. Typhimurium
4. After dehairing	0%	
5. After singeing	0%	
6. After powerhosing	7%	S. Agona
7. After evisceration	0%	
8. After washing	0%	
9. After chilling	0%	

The total bacterial counts increased by 0.5 $\log_{10}$ cfu cm^{-2} after bleeding. More importantly, *Salmonella* was subsequently detected on 50% of the carcasses, the highest detection level at any stage throughout the slaughter process. All of the isolates tested were *S. Typhimurium*.

Scalding and dehairing was combined making it physically impossible to swab the carcasses immediately after scalding. The temperature of the scald tank water was 62°C to 70°C and the pigs were immersed for 2 to 3 minutes. The combined effect of these 2 stages was a decrease of 1.5 $\log_{10}$ cfu cm^{-2} in total bacterial counts. *Salmonella* was not detected on any of the 60 carcasses at this stage.

Singeing was performed using hand-held gas torches. The whole carcass was carefully treated. The bacterial counts on the pork carcasses after the entire

dehairing process were reduced to 1.0 to 1.6 $\log_{10}$ cfu cm^{-2} and the incidence of *Salmonella* was zero.

Immediately after singeing the carcasses were power-hosed with municipal water heated to 40°C and applied at a pressure of 1030 kPa. This served as a pre-evisceration wash and removed any remaining burnt/singed material on the carcasses. As with the earlier power-hosing treatment, a visibly clean carcass did not necessarily mean improved carcass hygiene. Total bacterial counts increased to between 3.2 and 3.7 $\log_{10}$ cfu cm^{-2} ($P < 0.05$). *Salmonella* also reappeared on 7% of the carcasses. All of the isolates were identified as *S. Agona*. Evisceration did not cause further contamination and *Salmonella* was not found on the carcasses after this or at any subsequent stage.

The carcasses were washed immediately before chilling using a light spray of municipal water at approximately 15°C. Bacterial counts increased after washing to between 3.6 and 3.8 $\log_{10}$ cfu cm^{-2} and also after chilling, leaving the final bacterial numbers between 4.5 and 4.8 $\log_{10}$ cfu cm^{-2}.

BASELINE STUDIES IN A LARGE IRISH COMMERCIAL PORK PLANT

After bleeding, total viable counts on the ham, the belly and the neck areas of the carcasses were in the range 6.1 to 6.4 $\log_{10}$ cfu cm^{-2} (Figure 2). Scalding resulted in a decrease of approximately 3.5 $\log_{10}$ cfu cm^{-2} and the scald tank water was at 61°C. Dehairing increased contamination by 2 $\log_{10}$ cfu cm^{-2} which was reversed by the singeing process, leaving the total bacterial counts at 1.8 to 2.3 $\log_{10}$ cfu cm^{-2} with a difference ($P < 0.001$) between the counts on the neck and those on the other two areas. Contamination increased to approximately 3.5 $\log_{10}$ cfu cm^{-2} as a result of polishing and remained the same after evisceration, although the bacterial spread was uneven and the belly was more contaminated ($P < 0.05$) than the ham or the neck. During chilling, bacterial counts on the ham and neck increased and the final counts of 3.2 $\log_{10}$ cfu cm^{-2} (ham), 3.7 $\log_{10}$ cfu cm^{-2} (belly) and 3.5 $\log_{10}$ cfu cm^{-2} (neck) were all significantly different ($P < 0.001$).

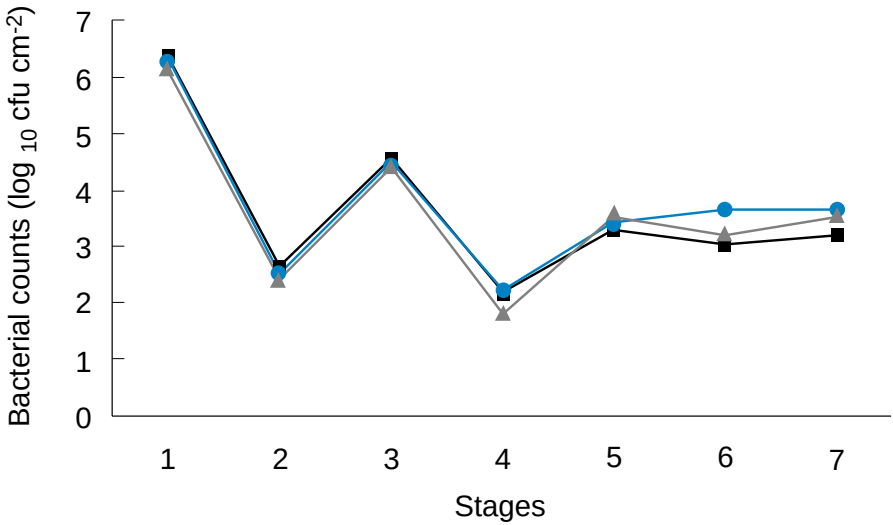

Figure 2: Bacterial contamination of pork carcasses in a large plant. Total viable counts (using PCA agar) on the ham (■), belly (●) and neck (▲) after (1) bleeding; (2) scalding; (3) dehairing; (4) singeing; (5) polishing; (6) evisceration; (7) chilling.

Initial coliform counts (Figure 3) were similar to total bacterial counts. However, coliforms were lower ($P < 0.05$) than total bacterial counts after dehairing, singeing and polishing. Initial coliform counts after bleeding of approximately 6 $\log_{10}$ cfu cm^{-2} decreased to 2.4 $\log_{10}$ cfu cm^{-2} as a result of scalding. Dehairing increased the coliform count which was again decreased by singeing. Polishing increased the coliform count. After evisceration the belly had the highest levels of contamination. The final coliform counts after chilling were in the range 3.0 to 3.6 $\log_{10}$ cfu cm^{-2}. The coliform resuscitation counts (using TSA/MAC agar, which detects injured as well as healthy cells) were similar to the total coliform counts (Figure 4), except after scalding-dehairing and chilling, where the resuscitation counts were higher ($P < 0.05$).

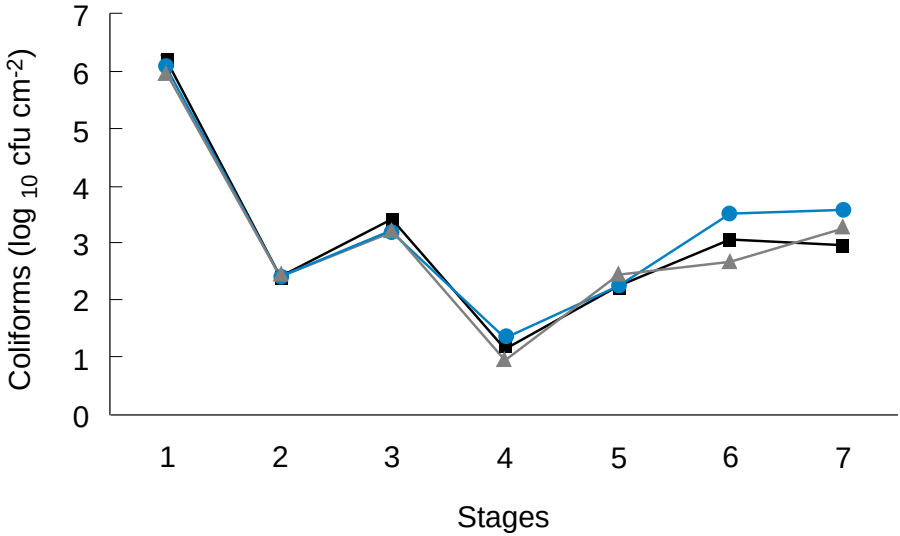

Figure 3: Total coliform counts (using MAC agar) on the ham (■), belly (●) and neck (▲) of pig carcasses in a large abattoir after (1) bleeding; (2) scalding; (3) dehairing; (4) singeing; (5) polishing; (6) evisceration; (7) chilling.

The prevalence of *Salmonella* in the large plant was 31% immediately after bleeding (Table 2). The isolates included *Salmonella Typhimurium*, *Salmonella Hadar, Salmonella Infantis* and *Salmonella Derby*. Scalding reduced the incidence to 1% and no *Salmonella* were detected in 108 samples of the scald tank water taken at different depths along the tank on two separate visits. The incidence increased to 7% after dehairing but these remaining *Salmonella* on the porcine skin were destroyed during singeing. Re-contamination of the carcasses did not occur during polishing but *Salmonella* were prevalent as a result of removing the porcine guts and 7% of the carcasses were contaminated.

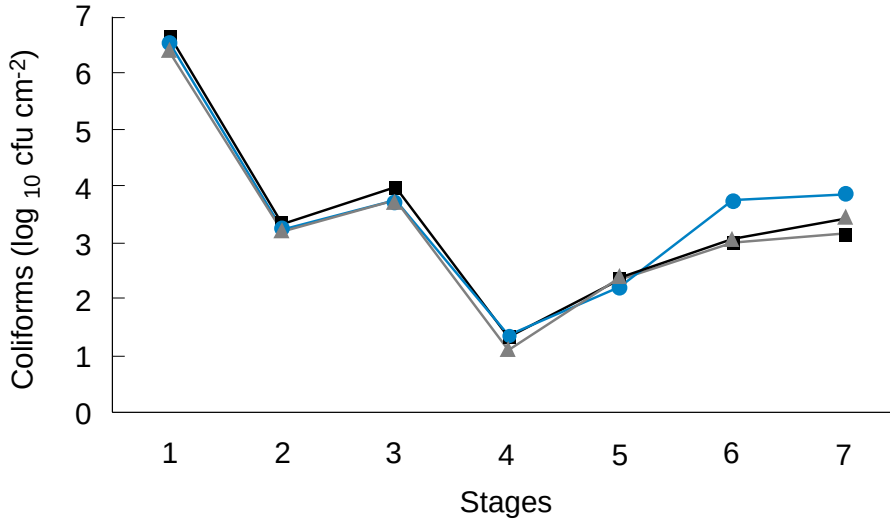

Figure 4: Total coliform resuscitation counts (TSA/MAC) on the ham (■), belly (●) and neck (▲) after (1) bleeding; (2) scalding; (3) dehairing; (4) singeing; (5) polishing; (6) evisceration; (7) chilling.

Table 2: The incidence of *Salmonella* on pork carcasses at each stage of slaughter in a large plant

Location	Incidence of *Salmonella*	Serotypes
After bleeding	31%	*S. Hadar, S. Typhimurium, S. Derby, S. Infantis*
After scalding	1%	*S. Derby*
After dehairing	7%	*S.Typhimurium, S. Derby*
After singeing	0%	
After polishing	0%	
After evisceration	7%	*S. Typhimurium*

AIRBORNE CONTAMINATION IN THE PORK SLAUGHTER ENVIRONMENT

Airborne contamination throughout a days' production was monitored in the large slaughter plant using two AES air samplers (which sampled air at a height of 1 metre above floor level) and settle plates (agar plates placed on the floor which measure the deposition or sedimentation of cells out of the air). Before production, at 06:00h, the level of airborne bacterial contamination (TVC) was the same ($P > 0.05$) throughout the slaughter plant at approximately 1.6 to 2.5 $\log_{10}$ cfu m^{-3} (Figure 5).

After 2 hours production, at 09:00h, TVCs increased to between 2.3 and 3.3 $\log_{10}$ cfu m^{-3}. Air contamination in the wet room (bleeding, scalding, dehairing and polishing) was now significantly higher than in the clean room (evisceration) and chiller and at 3.2 to 3.5 $\log_{10}$ cfu m^{-3} had reached its maximum level which was maintained throughout the rest of the days' production.

By 15:00h the number of airborne bacteria in the clean room had caught up with the wet room and there was no statistical difference ($P > 0.05$) between the 3.0 to 3.1 $\log_{10}$ cfu m^{-3} and the 3.4 to 3.6 $\log_{10}$ cfu m^{-3} detected in each, respectively. Clean room counts had reached their maximum and leveled off at 3.0 to 3.4 $\log_{10}$ cfu m^{-3}.

Airborne contamination in the chiller never reached the high counts obtained in the wet and clean room. At time 15:00h these were 2.2 $\log_{10}$ cfu m^{-3} and at 18:00h were 2.7 $\log_{10}$ cfu m^{-3}, less ($P < 0.05$) than those obtained at any of the other locations within the plant.

Salmonella were detected on 3 occasions, although all samples were tested for this pathogen; *S. Typhimurium* was detected twice at dehairing and once at evisceration.

There was a strong correlation between the total bacterial counts in the air (as detected using air samplers) and bacterial deposition onto the floor (as determined using settle plates) at bleeding, scalding, dehairing, evisceration 1 and evisceration 2, but not at polishing or chilling (Table 3).

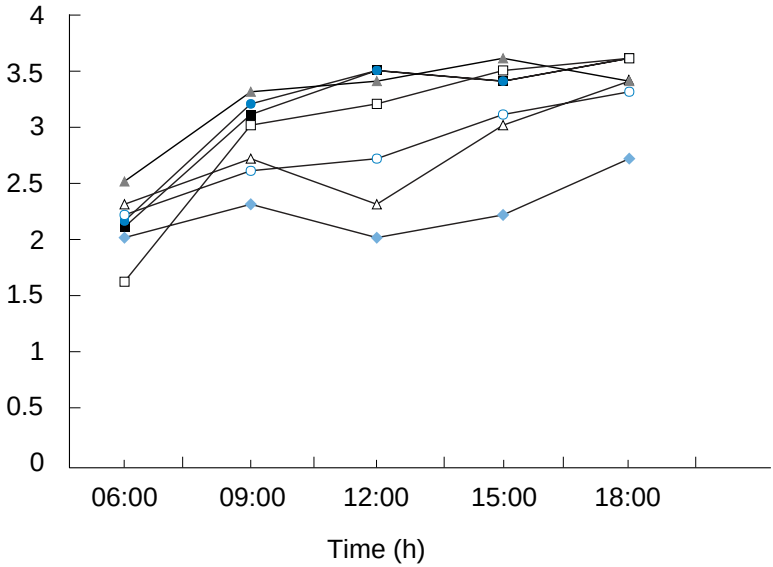

Figure 5: The increase in total viable counts (TVC) in the air during the working day at different locations within a large pork slaughter plant: bleeding (■), scalding (●), dehairing (▲), polishing (❑), evisceration 1 (O), evisceration 2 (△) and chilling (◆)

Table 3. Airborne bacterial contamination was measured at several locations on the slaughter line in a large pork plant using both air sampling equipment and agar settle plates. The correlation between the two methods is presented here.

Stage/location	Correlation coefficient	Probability
Bleeding	0.78	< 0.001
Scalding	0.61	< 0.05
Dehairing	0.77	< 0.001
Polishing	0.3	not significant
Evisceration 1	0.8	< 0.001
Evisceration 2	0.79	< 0.001
Chilling	0.12	not significant

INTERPRETATION OF RESULTS AND IMPLICATIONS FOR HACCP

On the farm

The incidence of *Salmonella* on pigs at the farm immediately before transport to the abattoir was 27%. Oosterom et al. (1985) found an incidence of 21% *Salmonella* in Dutch pigs, Epling et al., (1993) reported a 29% incidence, while Berends et al. (1998) suggested that up to 30% of finishing pigs in The Netherlands may shed this pathogen. However, in countries which have *Salmonella* control programmes at farm level, the incidence of *Salmonella* in the finishing pigs is much lower. The *Salmonella* carriage rate in Canada for example, is reported to be as low as 5.2% (Letellier et al., 1999) which is similar to the carriage rate found in Danish pigs (Christensen et al., 1999). To minimise the incidence and levels of *Salmonella* entering the abattoir it is imperative that effective control measures are taken at farm level. These should include the establishment of *Salmonella*-free areas in which the animals are reared, protection against contamination from feed, water and the environment, the establishment of *Salmonella*-free breeding stock and the transport of animals under conditions which do not allow contamination (Huis In't Veld et al., 1992). The observance of strict hygiene in pig fattening units would bring immediate benefits in the reduction and elimination of *Salmonella* (Christensen et al., 1999). These strategies should also include feed withdrawal (Miller et al., 1997), which ensures that the porcine gut is not full of feed at the time of slaughter and reduces the chance of gut rupture during evisceration. Sodium chlorate may also be applied in feed, which reduces the levels of *S. Typhimurium* (Anderson et al., 2001).

Pre-slaughter washing

Powerhosing of the live animals with cold water produced visibly clean pigs. However the total bacterial counts remained the same, while the incidence of *Salmonella* was reduced from 27% to 10%. Nevertheless, current animal welfare requirements discourage this activity.

Bleeding

Regardless of serotype, it is clear that bleeding resulted in a considerable increase in the overall *Salmonella* contamination rate of carcasses in the small plant. This

was attributed to the stunned animal being deposited on the floor and dragged to the point where it joined the rail. Although the floor was not swabbed, other studies, most notably by Mafu et al. (1989) and Hald et al. (1999) identified the floor as an important source of pathogens including *Salmonella*.

Scalding

In the smaller abattoir, there was no break between the scalding and the dehairing processes. Scalding was performed in water at a temperature of at least 62°C. Bacterial counts decreased by approximately 1.5 $\log_{10}$ cfu/cm^2 as a result of these two treatments and the incidence of *Salmonella* decreased from 50% to zero. In the larger abattoir the scalding process contributed to a 3.5 $\log_{10}$ cfu cm^{-2} reduction in bacterial count on the carcass surface and it was also observed that scalding in water at 61°C for approximately 8 minutes reduced the incidence of *Salmonella* from 31% to 1%. Furthermore, all scald tank water samples were negative for *Salmonella*. It is well established that if the temperature of the water is sufficiently high (above 60-62°C), enteric bacteria like *Salmonella*, *E. coli* and *Campylobacter* in the water and on the carcasses will be destroyed during scalding (Sorquist and Danielsson-Tham, 1990; Hald *et al.*, 1999; Davies *et al.*, 1999; Snijders., 1975; Mafu *et al.*, 1989). Gerats et al. (1981) reported a 2 $\log_{10}$ cfu cm^{-2} reduction in bacterial count following scalding. Berends et al. (1997) found no positive *Salmonella* in scald tank water at 60°C and Sorquist and Danielsson-Tham (1990) reported a 6 $\log_{10}$ cfu cm^{-2} reduction in *Salmonella* at 60°C after 1.7 to 2.2 minutes. Scalding might therefore be considered a CCP for the reduction of *Salmonella* and research by Hald et al. (1999), who observed *Salmonella* survival in the scald tank when the temperature decreased below 61°C, would suggest that the critical limit should be set at this temperature or higher.

Dehairing

There is little doubt that the dehairing machine is a major source of bacterial contamination (Morgan et al., 1987; Gill and Jones, 1995; Gill and Bryant, 1993; Davies et al., 1999; Yu et al., 1999) as was found to be the case in this research. In a similar study by Gill and Bryant (1993) up to 5 $\log_{10}$ cfu g^{-1} *Salmonella* spp. were obtained in 50% of debris samples taken from the

dehairing machine. Rivas et al., (2000) found that bacterial counts in the dehairing equipment ranged from 4.4 to 6.2 $\log_{10}$ cfu cm^{-2} 3 hours after slaughter had commenced. Morgan et al., (1987) suggested that contamination of the dehairing machine was due to faecal material escaping from the anus during this process. Insertion of a plastic cone, as is currently performed during lamb slaughter, prevents faecal contamination and should be used during pork slaughter to reduce faecal contamination of equipment and carcasses. Cleaning and disinfection of this equipment as part of the Good Manufacturing Practices (GMP) programme would also be expected to reduce cross contamination. However, Rivas et al. (2000) reported that cleaning and disinfection are often ineffective as the disinfectant does not reach all areas of the dehairer because of machine design. There is a need therefore to design dehairing equipment which can be effectively cleaned and disinfected, preferably using a cleaning-in-place system which could be applied on an ongoing basis throughout production.

Singeing

During singeing the surface temperature of the pork carcass may increase to 100°C (Borch *et al*, 1996). In the larger plant, singeing was performed using a commercial singer and resulted in a 2.5 $\log_{10}$ cfu cm^{-2} reduction in bacterial numbers. This finding is comparable with Troeger (1993) who reported a 2 $\log_{10}$ cfu cm^{-2} reduction in total bacterial counts and Gill and Bryant (1993) who obtained a 2 $\log_{10}$ cfu cm^{-2} reduction in *E. coli* counts. However, in the smaller operation a 3 $\log_{10}$ cfu cm^{-2} decrease in total bacterial counts was obtained after singeing using hand held units. Singeing may be considered to be a CCP or a GMP.

Polishing

Polishing was not performed in the smaller plant and it recontaminated the carcasses (1 $\log_{10}$ cfu cm^{-2}) in the larger slaughter operation. This may be due to cross contamination from the polishing equipment (Huis in't Veld et al., 1992) and/or due to redistribution of any bacterial contamination present on the carcasses after singeing (Snijders et al., 1984; Gill et al., 1995; Hald *et al.*, 1999). Effective cleaning of the polishing equipment is a prerequisite to improving carcass hygiene and is a GMP.

Washing of carcasses was used instead of polishing in the small plant. Washing resulted in 2.5 $\log_{10}$ cfu/cm^2 increase in contamination. It is well established that water must be heated to temperatures approaching 85°C or higher if a decontamination effect is to be obtained (Gill *et al.*, 1995). Van Netten *et al.* (1995) made a similar finding with *S. Typhimurium*.

Evisceration

The total bacterial counts were not affected by evisceration although the incidence of *Salmonella* increased from 0 to 7% in the larger plant. Evisceration is usually a major source of contamination on pork carcasses (Gill and Bryant, 1992; Berends et al, 1997; Hald *et al*, 1999) and Davies et al. (1999) reported increased incidence of *Salmonella* ranging from 4 to 32% after evisceration. Some authors consider evisceration to be a CCP (Borch *et al*, 1996) while others suggest that the low incidence of gut rupture and lack of corrective action when this does occur, means that evisceration is better controlled using Standard Operating Procedures (SOP) and Good Manufacturing Practices (GMP) (Anon, 1996). Regardless of the programme used, the training of operatives is fundamental to ensure that pork carcasses are not contaminated during evisceration (Borch et al., 1996). In the smaller plant, evisceration was performed by a single well trained operative, working at his own pace. As a result, these operations were performed properly and there was no increase in the bacterial count on the carcasses. In addition to observing best practice such as operating a 2 knife system where one knife was being sanitised at 82°C while the other was in use, this individual was also responsible for carcass inspection and trimming. Any blemishes or stains were trimmed and this may account for the decrease in *Salmonella* contamination. In larger plants where operatives are under pressure to achieve set production targets, evisceration may be used as a CCP if critical limits can be set and monitored effectively. These may be achieved by using the online monitoring system described by Bolton *et al.* (1999). This system has been scientifically validated in a commercial pork plant at Hatfield Quality Meats (Pennsylvania, USA). Over a 52 month period, carcass contamination rates decreased from 7.6% to 1.08% and total bacterial counts decreased by over 99.8% (Bolton et al., 1999).

Final washing

Final washing of the carcasses with cold potable was primarily applied to remove bone dust and blood clots and was ineffective as a decontamination treatment. Washing with cold or warm water should not be considered as a decontamination step during pork slaughter (Gill *et al.*, 1995). Its effects are related solely to improving carcass appearance and not to food safety. Van Netten *et al.* (1995) made a similar finding with *S. Typhimurium*. However, applying water at 85°C for 20 seconds achieved a 2 $\log_{10}$ cfu/cm^2 reduction in *E. coli* counts (Gill *et al.*, 1995). This finding was subsequently validated under commercial conditions using an apparatus that delivered sheets of water at 85°C for 15 seconds onto polished, uneviscerated pig carcasses (Gill *et al.*, 1997). The latter system consists of two horizontal headers each fitted with Floodjet™ nozzles arranged to deliver sheets of water in a free-fall manner rather than under pressure. The main bactericidal effect of these systems was thermal, although there may also have been a physical effect involving the removal of some bacteria as a result of washing.

Chilling

Chilling may be used as a CCP because it prevents the proliferation of bacteria on warm carcass surfaces. Some researchers have observed a reduction in the numbers of gram negative bacteria during chilling (Gill and Bryant, 1992). This is especially true of *Campylobacter*, which are particularly sensitive to drying, freezing and aerobic atmospheres (Borch *et al*, 1996). However, the present work found a slight increase in total bacterial counts. These variations may be due to different chilling parameters, such as air speed, air-flow, relative humidity, temperature profile for individual carcasses and carcass spacing (Feldhusen *et al.*, 1992), which are rarely reported when the effects of chilling on bacterial contamination is examined.

Air contamination

Airborne bacterial contamination of up to 3.5 $\log_{10}$ cfu m^{-3} was observed during this study which is similar to the maximal level of 3.4 $\log_{10}$ cfu m^{-3} reported by Kotula and Emswiler-Rose (1988) in a study conducted in a US pork plant and is within the range of 3.1 $\log_{10}$ cfu m^{-3} to 4.1 $\log_{10}$ cfu m^{-3}

reported by Rahkio and Korkeala (1997) in a study of four pork slaughter operations in Finland.

The pattern of air contamination decreased from wet room to clean room to chillers which was consistent with that reported for other slaughter facilities (Worfel et al., 1996) and the direction of airflow could not be clearly determined, which is also consistent with pork slaughter operations elsewhere (Rahkio and Korkeala, 1997). Steps could be taken to reduce pathogen spread through the air. Studies by Worfel et al. (1996) suggest that by extending the dividing wall to minimise the opening between the wet and clean rooms, airflow and bacterial spread would be considerably reduced.

This study, found a strong correlation between the air sample counts obtained with the AES impaction air sampler and the sedimentation counts obtained using settle plates, except at polishing and chilling. This result is at odds with Radmore and Luck (1984) who suggested that viable aerosol counts obtained using sedimentation methods, such as settle plates, are not at all or only weakly correlated with the counts obtained by other quantitative methods. However, the latter finding was based on air samples taken in a dairy plant where the environmental conditions and levels and types of bacterial contamination may account for the differences observed between sampling methods (Young and Frank, 1989).

CONCLUSIONS

- Power hosing the live animals in lairage did not reduce total bacterial contamination but decreased the incidence of Salmonella from 27% to 10%.
- Immersion in the scald tank decreased total bacterial contamination on the carcases by between 1.5 and 3.5 $\log_{10}$ cfu cm^{-1}.
- Singeing decreased total bacterial contamination on the carcasses by 2.5 to 3.0 $\log_{10}$ cfu cm^{-1}.
- Dehairing and polishing both increased bacterial contamination on the carcasses.

- Airborne bacteria reached 3.5 $\log_{10}$ cfu m^{-3} (with contamination apparently spreading from lairage to the wet room, clean room and into the chillers).
- Scalding, singeing, evisceration and chilling may be used as CCPs in pig slaughter.
- There was a strong correlation between the airborne contamination levels detected using air samplers and settle plates at all locations on the killing line except at the carcass polisher and in the chiller, where there was no correlation between the two methods.

RECOMMENDATIONS TO INDUSTRY

There are three main reasons as to why the Irish pork industry needs HACCP. Firstly, the EU Decision of the 8th June 2001 legally mandates full HACCP in all meat and poultry processing facilities throughout the Union. Failure to achieve compliance by June 2002 will result in failed audits and possibly enforced closure.

Secondly, the Irish pork industry is annually worth €280m. The national and international markets for Irish pork need to be protected from the adverse consequences and publicity associated with a major food poisoning scare.

Thirdly, public health needs to be protected. Pork is a potential source of *Salmonella* and other pathogens. HACCP is generally regarded as the best means of preventing contamination and thereby minimising the potential risk to the consumer.

This report provides the scientific basis for pork HACCP development and the following recommendations should be considered when these systems are being developed.

1. Feed should be withdrawn 12 hours before slaughter to minimise gut rupture during evisceration, which must be carefully performed by a well trained butcher.

2. Pigs should not be power-hosed as subsequent stages (scalding and singeing) destroy bacterial pathogens including *Salmonella* and power-hosing is contrary to good animal welfare standards.

3. Scald tank water should be at a minimum temperature of 61°C to prevent cross contamination of the carcasses with *Salmonella* during scalding.

4. Dehairing equipment and polishers should be cleaned as often as is possible to prevent the build up of pathogenic bacteria. Initially, all residues should be removed by power hosing with water at a pressure of 2000 to 3000 kPa. A layer of alkaline detergent should then be applied for 15 to 25 minutes before flushing off as above. The equipment should then be sanitised using a quaternary ammonia or other suitable sanitiser. The application of a plastic cone (such as that supplied by Macquip, Antrim, N. Ireland) is recommended to prevent leakage from the anus onto this equipment and thereby prevent carcass cross-contamination.

5. To minimise airborne contamination, effective ventilation and control of air flow should be applied. Zoning (the physical separation of highly contaminated areas such as the kill line from low or non-contaminated areas such as chills) should also be used.

6. The National Food Centre recently published 'HACCP for Irish Pork Slaughter' which provides the scientific basis for effective pork slaughter HACCP development and implementation and is available on request from the authors.

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