ORIGINAL ARTICLE

Slaughterfloor Decontamination of Pork Carcases with Hot Water or Acidified Sodium Chlorite – A Comparison in Two Australian Abattoirs

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Impacts

- Both hot water and acidified sodium chlorite treatment of pig carcases on the slaughter floor significantly improved their microbiological status as measured by *Salmonella*, *Escherichia coli* and Total Viable Count levels.
- Carcases were found to be aesthetically acceptable following treatment.
- This approach provides the pork industry with a risk management option to improve food safety and shelf life.

Keywords:
Salmonella; belly strip; *E. coli*; TVC; risk management; SANOVA™

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Summary

A decontamination trial on the effectiveness of hot water or acidified sodium chlorite (SANOVA™) treatment on *Salmonella* spp., *Escherichia coli* and Total Viable Count (TVC) was undertaken on pork carcases prior to primary chilling in two large pork abattoirs in Australia using belly-strip excision sampling. A total of 123 samples from Abattoir A and 400 samples from Abattoir B were cultured and analysed. Test pigs were selected from herds with a known high level of on-farm *Salmonella* infection. At Abattoir A, *Salmonella* spp. were not isolated from carcases. The prevalence of *E. coli* on control carcases was 92.9% compared with 9.8% for hot water and 12.5% for SANOVA™ treated carcases. The mean $\log_{10}$ *E. coli* concentration for control carcases was 0.89 cfu/gram, compared with −0.83 cfu/gram from hot water and −0.75 cfu/gram from SANOVA™ treated carcases. The mean $\log_{10}$ TVC for control carcases was 4.06 compared with 1.81 cfu/gram for hot water and 2.76 cfu/gram for SANOVA™ treated carcases. At Abattoir B, the prevalence of *Salmonella* on control carcases was 16% compared with 2.7% for hot water and 7.0% for SANOVA™ treated carcases. The prevalence of *E. coli* on control carcases was 69.3% compared with 22% for hot water and 30% for SANOVA™ treated carcases. The mean $\log_{10}$ *E. coli* concentration for control carcases was 0.45 cfu/gram, compared with −0.65 cfu/gram from hot water and −0.60 cfu/gram from SANOVA™ treated carcases. The mean $\log_{10}$ TVC for control carcases was 3.00 cfu/gram compared with 2.10 cfu/gram for hot water and 2.53 cfu/gram for SANOVA™ treated carcases. The reductions in prevalence and mean $\log_{10}$ concentrations in the present trial were all found to be statistically significant and indicate that carcases decontamination with either hot water or SANOVA™ are effective risk management options immediately available to the pork industry.

Introduction

In industrialized countries between 5% and 30% of all cases of foodborne *Salmonellosis* are estimated to have pork as the actual source (Berends et al., 1997). In Australia from 2004 to 2005, 5.34 million pigs with a gross farm value of $924 million were slaughtered at 20 major abattoirs (Anonymous, 2006). From 2003 to 2006 there

were 53 foodborne outbreaks attributed to microbial hazard : meat product combinations (excluding poultry meat) which were associated with the processing and catering sectors. While for 21 of these outbreaks no hazard was listed (M. Kirk and K. Fullerton, personal communication), *Salmonella* spp. were the most frequently identified hazard for the remaining 32 outbreaks and *Salmonella typhimurium* was the most commonly isolated serovar. Furthermore, of those outbreaks where *Salmonella* was the aetiology, pork was implicated in as many outbreaks as beef and sheep meats combined.

Routine monitoring of pig carcases in export abattoirs from January 2000 to September 2006 found the carcases prevalence of *Salmonella* to average 1.88% annually, with a range between 1.19% and 2.73%. The most frequent serovars isolated were *Salmonella* Derby, Anatum, Havana, London, Agona and Adelaide. Overall, *S. typhimurium* (including var Copenhagen) was isolated from 5.3% (7/132) of the positive samples (Hamilton et al., 2007a).

Although the European Union (EU) approach to *Salmonella* control has focused on the farm, in recognition that many aspects of *Salmonella* control programs are medium-term and include growers, feed millers and processors, the Danish *Salmonella* control program allows for carcases from high-risk herds to be subjected to hot-water decontamination as an additional intervention (Mousing et al., 1997). In addition to hot water, acidified sodium chlorite (SANOVA™; Ecolab Inc., St Paul, MN, USA) decontamination of pathogens on red meat and poultry was noted in reports from North America and Australia (Oyarzabal et al., 2004; Mehyar et al., 2005; Sexton et al., 2006). Miller et al. (2005) predict that in the US on-farm interventions (e.g. vaccination, meal feeding) are unlikely to be profitable from a socio-economic perspective, whereas rinsing carcases with and without sanitisers have favourable benefit : cost ratios.

This study was conducted to assess the effectiveness of hot water and SANOVA™ treatments on pig carcases naturally contaminated with *Salmonella* under Australian commercial slaughtering conditions. In addition, because Australian and USA regulatory authorities mandate routine carcases *Escherichia coli* monitoring (as an indicator of faecal contamination) and Australian and EU authorities mandate routine Total Viable Colonies (TVC) carcases monitoring (as an indicator of product hygienic handling and shelf life), these were also assessed. The results of the trial are presented in this communication.

Materials and Methods

Abattoir selection

The trial was conducted at two pig abattoirs in the medium to large category (annual slaughter >500 000 pigs), to evaluate the decontamination process under commercial slaughtering conditions. The selected abattoirs needed to periodically slaughter pigs from herds known to be infected with *Salmonella* spp., and to agree to participate in the trial.

Pig/herd selection

The aim was to select known *Salmonella* infected herds to ensure that the carcases used in the decontamination study had the maximum chance of being contaminated with *Salmonella* spp. To minimize testing costs herds that had been identified as *Salmonella* positive in other studies were utilized.

The herd selected for Abattoir A had rectal faecal samples (>10 grams/pig) collected on farm from individually identified abattoir trial pigs prior to slaughter. The pigs were sampled twice (5 weeks and 5 days) prior to slaughter and the presence of *Salmonella* confirmed (29% and 15% positive, respectively).

For Abattoir B, three related herds suspected of having a high level of *Salmonella* infection were sampled at the rate of 10 pen faecal samples per herd, some 2 months prior to the trial. A single pen faecal sample is defined as a composite of five 10 g samples of faeces from different fresh faecal pats. A heavily infected herd (9/10 positive pen samples) was selected for the decontamination trial.

Carcass selection/trial design

At each abattoir, trial pigs were slaughtered over 3 days, with a maximum of 392 carcases at Abattoir A and 450 at Abattoir B. Trial pigs were slaughtered and sampled at the end of the day at Abattoir A and early in the second slaughter shift of the day at Abattoir B. On each sampling day the trial carcases were subjected to one of three treatments:

1 Up to 50 carcases standard hygienic slaughter (Controls).
2 Up to 50 carcases standard hygienic slaughter plus a final 15 s rinse with hot water (83.5°C at Abattoir A, 81.9°C at Abattoir B).
3 Up to 50 carcases standard hygienic slaughter plus a final 15 s rinse with SANOVA™ solution (ECOLAB Inc) at ambient temperature.

SANOVA™ is an acidified sodium chlorite solution with a pH between 2.4 and 2.6 (generated by mixing the pre-cursers SANOVA Activator and SANOVA Base), which produces the microbiologically active chlorous acid. The order of treatments was rotated on each day in a 3 × 3 Latin-square arrangement.

Dose selection and application

Both hot water and SANOVA™ were applied for approximately 15 s per carcase side, with hot water being applied as a high volume continuous cascade (approx. 40 l/side) and SANOVA™ as a low volume pressurized spray (approx. 4 l/side). To achieve the correct treatment times, it was necessary to slow the chain at Abattoir A to half speed during the trial i.e. 2 carcases/min. At Abattoir B decontamination occurred at normal chain speeds: i.e. 5.5 carcases/min.

Sample collection

Using a carcass excision sampling technique described by Swanenburg et al. (2003), a total of 392 and 450 belly strips were collected from carcases at the end of the slaughter chains at Abattoirs A and B, respectively, just prior to entering the chillers. The belly strip is a thin continuous strip of belly (1–2 cm wide) incised from the edge of the evisceration opening and stretching from the inguinal region to the xiphoid cartilage, comprising skin, muscle, fat and peritoneum. The use of this excision technique can increase the detection of *Salmonella* on pig carcases by up to 7-fold compared to swabbing (Hamilton et al., 2007b). Care was taken to avoid incising the inguinal lymph node (a potential intratissue source of *Salmonella* contamination). For speed/safety of sampling, an abattoir employee removed the belly strips using an aseptic technique that was closely monitored. To eliminate any slaughter or evisceration confounder, belly strips were collected from alternate sides and kept at 4°C until processed. Belly strips were used for *Salmonella, E. coli* and TVC culture.

Laboratory methods – faecal samples

Faecal samples were processed for *Salmonella*. A maximum of 25 g of faeces was weighed into a sterile stomacher bag and diluted 1 : 10 w/v with Buffered Peptone Water (BPW) (Oxoid CM509, Oxoid Australia Pty Ltd, Thebarton, Australia). Where there were less than 25 g the 1 : 10 w/v dilution was maintained by reducing the BPW accordingly. The BPW diluted faeces were incubated at 37 ± 1°C for 24 ± 3 h then inoculated onto Modified Semi-solid Rappaport Vassiliadis (MSRV) medium (Oxoid CM0910, Oxoid Australia Pty Ltd) as follows. Three 33 μl drops of the pre-enrichment culture were inoculated in separate spots on the surface of the MSRV Medium plates. The plates were incubated in an upright position at 42°C for up to 24 h. The plates were examined for motile bacteria indicated by a halo of growth originating from the inoculation spot. Sub-cultures were taken from the outside edge of the halo onto CLED agar (Oxoid PP2015, Oxoid Australia Pty Ltd) to confirm purity. *Salmonella* was confirmed using Serobact *Salmonella* Latex (Oxoid Australia). Typical colonies not giving a positive reaction with the latex agglutination were identified using the Microbact™ 12E identification system.

Laboratory methods – belly strips

Each belly strip was collected into a sterile stomacher bag on the slaughter floor. Samples were chilled at 4°C until testing. At the lab the belly strip was weighed and an equal amount of BPW (Oxoid CM509, Oxoid Australia Pty Ltd) added. The belly strip was then stomached for 60 s. A 1 ml aliquot was taken to estimate *E. coli* and TVC and the remainder processed for *Salmonella*. Samples were examined for *E. coli* (as an indication of faecal contamination) and TVC as a general indicator of carcases hygiene status. In addition, meat processors are interested in TVC as an indicator of potential shelf life.

Salmonella

All samples were incubated at 37°C ± 1°C for 18 h ± 2 h. Aliquots of 0.1 ml and a 1.0 ml of each incubated BPW suspension were then inoculated into 10 ml volumes of Rappaport–Vassiliadis Soy broth (RVS) (Oxoid Pty Ltd) and Muller–Kauffmann tetrathionate/novobicin broth (MKTTn, Oxoid Pty Ltd), respectively. These were then incubated for 24 h ± 3 h at 41.5°C ± 1°C and incubated at 37°C ± 1°C, respectively.

For all samples, loopfuls of RVs and MKTTn broth were plated on Xylose Lysine Desoxycholate (XLD, Oxoid Pty Ltd) and Brilliant Green (BGA, Oxoid Pty Ltd) agar plates and incubated at 37°C ± 1°C for 24 h ± 3 h. One typical colony from each XLD and BGA plate was subcultured for purity onto Cystine–Lactose–Electrolyte Deficient (CLED) agar and incubated at 37°C ± 1°C for 24 h ± 3 h with typical colonies confirmed by latex agglutination using Serobact™ *Salmonella*. Colonies that were latex agglutination negative were checked by biochemistry (MICROBACT™ 12E, Oxoid Pty Ltd).

Isolates presumptively identified as *Salmonella* were forwarded for serotyping to the Australian *Salmonella* Reference Laboratory at the Institute of Medical and Veterinary Science, Adelaide.

Escherichia coli and Total Viable Count

From the 1 ml aliquot taken immediately after stomaching, as appropriate, 1 : 10 serial dilutions of the BPW suspension were prepared in 0.1% peptone diluent and 1 ml from each dilution inoculated onto either Aerobic Plant Count Petrifilm (3 M) or *E. coli* Petrifilm (3 M) and incubated at 48 h ± 3 h at 35°C ± 1°C. Colonies were

Table 1. Effect of hot water and SANOVA™ on the microbiological status of pork carcases

	Control	Hot water	SANOVA	*P*-value[c]
Abattoir A				
n (Day 3)	42	41	40	
Mean $\log_{10}$ TVC (SE)[a]	4.06 (0.42)	1.81 (0.55)	2.76 (0.53)	<0.0001
Escherichia coli positive[b]	39/42 (92.9%; 80.5–98.5%)	4/41 (9.8%; 2.7–23.1%)	5/40 (12.5%; 4.2–26.8%)	<0.0001
Mean $\log_{10}$ *E. coli* (SE)	0.89 (0.11)	−0.83 (0.21)	−0.75 (0.19)	<0.001
Salmonella positive	0/42	0/41	0/40	n/a
Abattoir B				
n	150	150	100	
Mean $\log_{10}$ TVC (SE)	3.00 (0.40)	2.10 (0.77)	2.53 (0.56)	<0.001
E. coli positive	104/150 (69.3%; 61.3–76.6%)	33/150 (22%; 15.7–29.5%)	30/100 (30%; 21.2–40.0%)	<0.001
Mean $\log_{10}$ *E. coli* (SE)	0.45 (0.08)	−0.65 (0.11)	−0.60 (0.13)	0.007
Salmonella positive[b]	24/150 (16%; 10.5–22.9%)	4/150 (2.7%; 0.7–6.7%)	7/100 (7%; 2.9–13.9%)	<0.001

[a]All Mean Concentrations – TVC and *E. coli* – are reported as $\log_{10}$ cfu/g.
[b]Values in brackets indicate percentage positive and 95% confidence interval.
[c]*P*-values are for the overall test used to assess differences between the three treatments (Control, Hot water and SANOVA™).
TVC, total viable count; SE, Standard Error.

identified and counted according to the manufacturer's instructions. The limits of detection were between 10 and 250 000 cfu/gram for TVC and between 1 and 500 for *E. coli*.

Sample integrity

The integrity of the samples obtained on the first 2 days of sampling from Abattoir A was compromised. On Day 1 they (149 samples) were exposed to high air-shipment temperatures (23.9°C on arrival at the laboratory) and on Day 2 the samples (120) were misplaced for 48 h by the airline. Therefore, only the 123 pig carcases sampled on Day 3 from Abattoir A were analysed (Table 1).

At Abattoir B on Day 3 the hot water temperature was reduced from 81°C to an average temperature of 76.5°C due to company concerns over slight superficial discolouration reported in the boning rooms. In addition, the chlorite concentration of SANOVA™ was reduced by 100 ppm/day over the 3 days from 1100 to 900 ppm in an attempt to reduce the bleaching effect. Preliminary analyses were performed to assess the effects of these changes.[1] The results (not presented) of these analyses indicated that there was no significant difference in daily mean levels of TVC, *E. coli* or *Salmonella* as a result of changes to the hot water and SANOVA™ treatments. Therefore, the changes to these treatments that occurred over the sampling period were not considered in the subsequent analyses. At Abattoir B it was observed that 12 consecutive carcases from the Day 3 SANOVA™ treatment group were contaminated with the same serovar of *Salmonella*. It is suspected that a major contamination event occurred and so the 50 × Day 3 SANOVA™ samples were excluded from all analyses, leaving a total of 400 samples from Abattoir B.

[1]The preliminary analyses were performed separately on the hot water and SANOVA™ data. The null hypotheses for these assessments were that the mean concentration/prevalence of *Salmonella, E. coli* and TVC was the same for each day. The statistical methods utilized were those described in Statistical analysis.

Statistical analysis

A significance level of 0.05 was used to determine statistical significance. A backward selection approach was used to eliminate insignificant terms from the models.

Each abattoir was analysed separately. Fisher's Exact Test was used to test for differences in the carcases prevalence of *Salmonella* and the prevalence of *E. coli* between all three treatments. When significant differences were detected, Fisher's Exact Test was also used to assess the differences between each pair of treatments in turn.

Data for $\log_{10}$ TVC per gram were analysed by analysis of variance to test for mean differences between the three treatments. In this analysis, samples less than the lower limit of detection (< 10 cfu/g) were assumed to be equal to the limit of detection. This approach is unlikely to have a significant practical impact as there were only two such observations for Abattoir A and eight for Abattoir B. The full model consisted of an overall mean and fixed effects for (i) the day of sampling (to allow for the blocking structure – Abattoir B only) and (ii) the treatment. The day effect was fitted as a fixed effect to maintain close compatibility with the censored regression approach, which currently cannot fit random effects. The models were checked using standard diagnostic tools, including Normal quantile plots and residual plots.

A Tobit (censored) regression was performed for $\log_{10}$ *E. coli* per gram. This technique allows for the censored nature of the data (i.e. the actual amount of *E. coli* in a number of samples is undetected or unknown because it is less or greater than the limit of detection). The advantage is that all observations can be included, including those samples where *E. coli* was undetected, leading to more realistic comparisons between the treatments (Lorimer and Kiermeier, 2007). The full model consisted of an overall mean and fixed effects for (i) day of sampling (Abattoir B only) and (ii) the treatment. The model assumes that the residuals are normally distributed, but due to the amount of censoring present in the two treatment groups, diagnostics of the models fit were not feasible.

All analyses were performed in R 2.10.1 (R Development Core Team, 2009).

Organoleptic changes

At both abattoirs experienced company slaughter floor and boning room supervisors were asked to assess whether the treated product would be acceptable to their customers. Although highly subjective, customer acceptance/rejection is a significant factor that is likely to influence the pork industry's adoption of slaughter floor decontamination treatments.

Results

Overall hot water and SANOVA™ had significant effects on the prevalence of *Salmonella* and *E. coli* and the mean $\log_{10}$ concentration of *E. coli* and TVC (Table 1).

Salmonella

At Abattoir A, no *Salmonella* spp. were isolated from any carcase (including the 269 excluded from later analysis) even though the pigs were sourced from an infected herd. At Abattoir B, both the hot water and SANOVA™ treated carcases had a significantly lower prevalence of *Salmonella* contamination compared to the control ($P < 0.001$). The prevalence of *Salmonella* was not significantly different ($P = 0.12$) between the hot water and SANOVA™ treatments.

Escherichia coli and total viable count

The prevalence of *E. coli* at Abattoir A was significantly reduced for hot water and SANOVA™ carcases compared to the control ($P < 0.001$; differences of 83.1% and 80.4%, respectively), and the two treatments did not differ significantly ($P = 0.74$). Similarly at Abattoir B, the prevalence of *E. coli* was significantly lower in the hot water and SANOVA™ treated carcases compared to the control ($P < 0.001$; differences of 47.3% and 39.3%, respectively), and the two treatments did not differ significantly ($P = 0.18$). In addition, at both abattoirs the *E. coli* counts were significantly lower in carcases treated with hot water or SANOVA™, compared to the control ($P < 0.001$), and the differences between the two treatments were not significant (Abattoir A: $P = 0.73$; Abattoir B: $P = 0.69$). At Abattoir A the mean log reductions in *E. coli* by hot water and SANOVA™ were 1.72 and 1.64 compared to the control. At Abattoir B the impact was less with a mean log reduction of 1.1 for hot water and 1.05 for SANOVA™ compared to the control.

At both abattoirs TVCs were significantly lower in carcases treated with either hot water or SANOVA™ compared to the control ($P < 0.001$). At Abattoir A the mean log reduction in TVC was 2.25 for hot water and 1.3 for SANOVA™ compared to the control, and the difference between the two treatments was significant ($P < 0.001$). At Abattoir B, the impact was less, with mean log reduction in TVC of 0.9 for hot water and 0.47 for SANOVA™ compared to the control. The difference between the two treatments was also significant ($P < 0.001$).

Organoleptic observations

Immediately following the 15-s treatment with hot water, exposed muscle on the carcases had a grey 'cooked' appearance, particularly the leg, sternum and neck. Within half an hour they had begun to recover some of their 'bloom' (an industry term describing the visual appearance of meat, encompassing both colour and freshness) and by the next morning, in the opinion of the abattoir staff, the treated carcases were almost indistinguishable from untreated carcases. In their view they would be aesthetically acceptable to their markets, both export and domestic. At Abattoir B there was initial unsought feedback from a domestic retailer that the carcases 'appeared a bit different' and required some superficial trimming, however, reducing the treatment temperature on Day 3 from 81.9 to 76.5°C apparently resolved the issue (i.e. there was no further negative feedback).

The SANOVA™ treatment 'whitened' both the skin and the fat, but this was judged by the companies to be a positive aesthetic improvement, particularly for Asian export markets.

Discussion

Research into an effective means of decontaminating slaughter carcases has been ongoing over many years on a

variety of meat species: sheep (Smith and Graham, 1978; Gill et al., 1999), beef (Davey, 1989; Davey and Smith, 1989; Gill and Launders, 2003), pigs (Gill et al., 1995, 1999; Albans and Sørensen, 2009) and poultry (Oyarzabal et al., 2004; Mehyar et al., 2005; Sexton et al., 2006).

This trial of two commercially available slaughter floor interventions (hot water and SANOVA™) represents a new perspective on carcase decontamination due to a unique combination of approaches:

1 It was conducted under commercial slaughtering conditions.
2 It relied on 'natural' carcase contamination.
3 It utilized a new, more sensitive excision sampling technique which allowed a direct assessment of the impact of decontamination on carcase *Salmonella* spp.
4 It included a meat industry assessment of the aesthetic acceptability of treated carcases to the meat trade.

Hot water treatment of carcases is allowed in the USA, Europe and Australia. SANOVA™ is approved for use on edible product in the USA, while the two components of SANOVA – citric acid and sodium chlorite – are approved processing aids in Australia. Further, the Netherlands recommended over a decade ago that carcase decontamination using safe substances should be allowed in the EU as long as the slaughterhouse adheres to Good Manufacturing Principles (Berends et al., 1997).

In this study both hot water and SANOVA™ treatment had significant reduction effects on the prevalence of *Salmonella* and *E. coli* and the mean $\log_{10}$ concentration of *E. coli* and TVC (Table 1). However, as the hazard was not eliminated these interventions would not meet the generally accepted definition of a Critical Control Point (Anonymous, 1998).

The failure to isolate *Salmonella* spp. from carcases at Abattoir A was unexpected in view of the confirmation of infection in pre-slaughter pigs (15% of animals 5 days prior to slaughter). However, because of a previous market access problem, this abattoir had spent the previous 12 months focused on slaughtering techniques to try and reduce *Salmonella* contamination.

Although it was observed that Abattoir A had higher levels of *E. coli* and TVC in the control group compared to Abattoir B (mean log difference of 1.06 and 0.43, respectively), the intervention treatments achieved substantial reductions in hygiene indicator concentration at both abattoirs.

As indicated in the Methods, the integrity of samples from trial days 1 and 2 at Abattoir A was compromised. While this was unfortunate and clearly reduces the power of the study, it is not believed that this biases the results in any way. In contrast, it could be expected that the exclusion of the 50 SANOVA™ treated samples collected on Day 3 could bias the results, especially since their exclusion was due to the detection of the same *Salmonella* serovar from twelve consecutive carcase. However, this is only the case if the observed contamination is not attributable to a special event, which justifies the exclusion.

In the context of reducing risk, Hanssen et al. (2007) proposed that persistent abattoir contamination is proportionally an important source of carcase contamination and therefore on-farm reduction measures may have limited impact. Further, the impact of such carcase decontamination procedures can be assessed using predictive approaches. Using a US farm-to-fork model covering the pork production chain up to the point of producing a chilled pork carcases, Miller et al. (2005) estimated human health costs and risk associated with *Salmonella* in pork. Sensitivity and scenario analyses indicated that changes in *Salmonella* status during processing are more important for human health risk and were found to have a higher benefit : cost ratio when compared with on-farm strategies for *Salmonella* control. Specifically benefit : cost ratios are < 1 for the on-farm interventions (e.g. vaccination, meal feeding), indicating they are not likely to be profitable from a socio-economic perspective, whereas rinsing carcases at various temperatures with and without sanitisers have favourable benefit : cost ratios >1. A 10% reduction in prevalence during slaughter and processing was predicted to reduce human salmonellosis by approximately 75%, whereas a 10% reduction on-farm would reduce salmonellosis by 2.3%. Transport and lairage changes were found to have a similar effect as on-farm reductions.

Miller et al. (2005) conclude that this type of modelling is useful for the evaluation of the relative cost-effectiveness at different points along the food chain when allocating limited food safety expenditure. Their results indicate that the closer to the consumer the control strategy can be employed, the more likely there will be a direct and major effect on salmonellosis. These US authors recommend that further data on the various carcase rinsing options would enhance these results. In this context, these Australian commercial trial results provide the pork industry with practical and effective hygiene interventions. Ultimately, the uptake will be dictated by customer specifications in relation to the use of chemical decontaminants, costs versus potential benefits from enhanced shelf life and customer satisfaction with carcase quality.

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