Preventive strategies during slaughter of poultry, to improve food safety

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Summary

During primary processing of poultry, a massive cross-contamination takes place by Enterobacteriaceae and Campylobacter. Developing a cost-effective intervention requires a thorough knowledge of these routes. Faeces may be released during hanging, stunning and bleeding, but also during scalding, and plucking. This explains why earlier interventions like multistage scalding resulted in lower counts in the scalding water, but not necessarily in lower counts on the skin after plucking. Feed withdrawal leads to less physical contents of the intestinal tract, but also to increased counts of Enterobacteriaceae and Campylobacter.

To address this, equipment was developed to exert an external pressure on the abdominal skin, to force faeces out of the lower intestinal tract, just before scalding, and to remove the released faeces from the carcass directly, by a set of nozzles.

To validate the performance, this equipment, called the Preventer, was installed in one of two practically identical slaughter lines, fed with the same flock. Microbiological research by an external lab revealed that Enterobacterial counts in both scald tanks of the test line were significantly lower during the 4 test days.

After plucking, Enterobacterial counts of breast skin samples in the test line were also significantly lower.

During two test days, Campylobacter-positive flocks were processed. Campylobacter species were generally not detected in the scald water of 52° C (log_{10} cfu/ml < 1,3), but breast skin samples after plucking showed an average Campylobacter count of log_{10} cfu/gr = 3,71 in the reference line and 3,21 in the test line.

It is concluded that this intervention significantly contributes to reduced bacterial counts (Enterobacteriaceae, Campylobacter) after plucking, and should be considered as Good Manufacturing Practice. This intervention could be a useful basis for decontamination, both for principal as for technological reasons.

Introduction

Development of a cost-effective intervention to improve processing hygiene requires an analysis of the contamination of the live bird, the contamination routes and the impact of subsequent processing steps. Healthy birds, entering the slaughter plant, primarily contain bacteria in/on:

SKIN

Skin flora is dominated by Micrococcaceae (Thomas 1980), e.g. Staphylococcus aureus is typically located on the skin (Mead 1989). Berrang (2000) found a mean log_{10} cfu Campylobacter per gram of skin = 3.8.

FEATHERS

Faecal contamination of the feathers contributes to the spread of Enterobacteriaceae (Mulder 1977), but hardly to the spread of Campylobacter (Genegiorgis 1986). During transport, faeces may be released and may stick to the birds (Papa 1989). Berrang (2000) found a mean log_{10} cfu Campylobacter per gram of feathers = 5.4.

CROP

Large amounts of Enterobacteria (like Salmonella), and Campylobacter may be present in the crop, especially after a long feed withdrawal time (Hinton, 2000 b).

Barnhart (1999) found that feed withdrawal may lead to coprophagy, leading to a significant contamination with Salmonella of the crop. This conclusion is in line with findings of Ramirez (1997) who found that feed withdrawal increases the incidence of Salmonella in broiler crops and caeca prior to slaughter. During feed withdrawal, the pH in crop and caeca becomes more favourable for Salmonella and Campylobacter.

Crops are 3.5 times more likely to be contaminated with Salmonella, than caeca (Barnhart 1999), and Berrang (2000) found a mean $\log_{10}$ cfu Campylobacter per gram of crop contents of 4.7. Sams (2003) states that the crop is known to be important in the bacterial cross contamination.

CAECA

The caeca are identified as the primary site of Salmonella colonization (Corrier 1999) and of Campylobacter colonization. Ramirez (1997) found that the incidence of Salmonella-positive caeca was higher following long feed withdrawal. Hinton (2000a) found no significant reductions in weight of the caecal contents during feed withdrawal. Berrang (2000) found a mean $\log_{10}$ cfu Campylobacter per gram of caecal contents of 7.3.

COLON

Fresh faeces, present in the intestinal tract, contain high numbers of Enterobacteriaceae; $\log_{10}$ cfu /gram varies from 7.5 to 8.0 (Mulder (1977), (Lillard 1990), (Heemskerk 1991). Campylobacter contamination of the carcasses is almost entirely of faecal origin. (Oosterom 1983). Berrang (2000) found a mean $\log_{10}$ cfu Campylobacter per gram of colon contents of 7.2.

WHAT HAPPENS DURING SUBSEQUENT PROCESSING STAGES?

Feed withdrawal

Obviously, after feed withdrawal, the content of the intestines is reduced in time. Ramirez (1997) found that feed withdrawal increased the incidence of Salmonella in broiler crops and caeca prior to slaughter. This may explain why Barnhart (1999) found an increased incidence of Salmonella due to feed withdrawal.

Timing of feed withdrawal is hard to manage, as feed is withdrawn batch wise, while the slaughter takes place continuously; the last bird of the flock may be processed 3 hours later than the first bird of the same flock. Feed withdrawal may also affect animal welfare (indicated by stress, coprophagy) and weight loss. Bilgili (1988) found some significant relations between feed withdrawal time, and shear force of several parts of the intestinal tract.

Stunning, killing and bleeding

Many birds release faeces during stunning (Bryan 1995) and bleeding (Papa 1989).

Immersion scalding

Faeces, released in previous stages, enter the scald water, providing a massive potential for cross contamination. Birds may also involuntarily release faeces during scalding, due to peristaltic action of the intestines (Humphrey 1981, referring to Crabb 1971). The release of faecal matter results in a decrease of the pH to a level of around 6.0, reducing the heat-sensitivity of Salmonella species and increasing the survival rates of Salmonella (Humphrey 1981a, 1981b), (Okrend 1986). Hudson (1987) found that organic material in the scald water significantly decreased the heat sensitivity of Campylobacter jejuni and Salmonella during scalding.

The bacterial counts reach an equilibrium point after 1 to 2 hours of production (Veerkamp 1989); the equilibrium count is related to the amount of bacteria released per bird.

During scalding, the birds are washed, due to the turbulence of the water, (Veerkamp, 1989). The total count may drop 1 log during scalding at 52ºC , and 2 log during scalding at 60ºC. Humphrey (1984) found a significant reduction in the bacterial load on the carcasses ($p<0,001$), after scalding at 52 +/- 0.5ºC.

Izat (1988) found a significant decrease of the Campylobacter counts (- 1,84 log) and concluded that the scalding operation is the most effective process for decreasing overall microbial levels on the surface of poultry carcasses.

The bacterial quality of adherent water on birds leaving the scalder can be improved by multistage scalding, countercurrent scalding, and extra suppletion; model calculations indicate that extra suppletion of fresh water has a limited impact on bacterial counts in the adherent water. (Veerkamp 1989, Cason 1999). Vapour scalding reduces the potential for Salmonella cross contamination (Humphrey 1984).

However, both the washing effect and the thermal reduction of contamination during vapour scalding are small, as exposure time is equal to the scalding time, and the skin provides a protective environment (Humphrey 1984).

Attachment. Thomas (1987 describes a gradual process of retention, entrapment and attachment of bacteria to the bird skin, making organisms harder to remove, and more resistant to heat (Humphrey 1987), due to the protection by the skin. Attached bacteria easily survive scalding, due to the protection by the skin, and the limited duration of the exposure.

Example: Assuming a $D_{52°C}$ of 61.72 minutes for attached S. typhimurium (Humphrey 1984) and a scalding time of 4 minutes, a reduction of only $\Delta \log_{10}$ cfu/gr of 4/61.72 = 0.06 can be expected.

In a similar way, the reduction during a 2-minute hard scald ($D_{52°C}$ of 61.72 minutes, Z=5°C, so $D_{57°C}$ = 6.17 min.) can be estimated to be (2 / 6.17) log units, = 0.32 log units. After hard scalding, the epidermal layer is removed during plucking, providing better opportunities for Salmonella and Campylobacter to attach (Slavik 1995).

Clearly, attached bacteria are hardly reduced during scalding, while loose bacteria are significantly reduced, so there are good reasons to avoid that faecal bacteria contact the skin during scalding, and gradually become attached to it.

PLUCKING

Abu-Ruwaida (1994) found a major increase of Campylobacter- and Enterobacteriaceae counts on neck skin, from pre-scald to post plucking. Izat (1988) found a significant decrease of Campylobacter counts on the carcasses during scalding, and a significant increase during plucking. Musgrove (1997) found that plugging of the vent before plucking resulted in lower Campylobacter prevalence, and lower numbers of Campylobacter per carcass and concluded that cross contamination of Campylobacter is probably due to escape of faeces during plucking.

Berrang (2001) confirmed that an increase in the recovery of Campylobacter can be related to the escape of contaminated faeces from the cloaca during defeathering. Obviously, the escape of faeces during plucking provides a massive source for both recontamination and cross contamination, easily nullifying any improvement in scalding hygiene.

So, an improvement of the bacterial quality of the bird after plucking can only be achieved if the escape of faeces during plucking is reduced.

HEAD PULLING

The crop is 86 times more likely to tear during processing, than the caeca (Hargis 1995). This rupture of the crop occurs during head pulling, after a shallow cut, not cutting the esophagus. The contaminated and ruptured crop may contaminate the body cavity during evisceration. The required intervention is a cut through the esophagus, leaving the crop intact during headpulling. The eviscerator needs to remove the entire esophagus, including the crop.

Materials and methods

A piece of equipment was developed, to force the release and removal of faeces, just before the scalder. Aim is, to reduce the release of bacteria during scalding and plucking, and to reduce the amount of organic material entering the scalder.

The Preventer was placed in a commercial processing plant in a “twin” slaughterline, processing birds from the same flock, with the same equipment, at the same line speed, allowing a fair comparison between the test line and the reference line.

Feed had been withdrawn from the birds 7 to 13 hours prior to slaughter, average 11 hours. Daily cleaning of the equipment was done as usual by the usual cleaning crew.

Scald water samples and skin samples were collected, from both the test line and the reference line, at the start of processing, and after 1, 2, 3, 4 and 8 hours of processing at a line speed of 5500 bph. Samples were collected, processed and reported by a certified laboratory.

Birds were scalded in a two-tank system, 2 x 90 seconds at 52.5 ºC.

Skin figures: each figure (Table 1, Table 2) is based on average of 10 individually processed skin samples of the central breast skin, about 10 gram, collected aseptically after plucking.

Scald water figures (Table 1, Table 2): the counts at t = 0 hours are taken within 5 minutes after start of processing, they are not included in the average counts , as they indicate the initial status, rather than the impact of the intervention.

Enterobacteriaceae (cfu/ml or cfu/g) according to ISO 7402: enumeration on violet red bile dextrose (VRBD) agar after 20-24 hours of incubation at 37 ºC.

Campylobacter (cfu/ml or cfu/g) according to ISO/CD 10272-2. Enumeration on charcoal cefoperazone deoxycholate agar (CCDA) after 40-48 hours incubation at 41.5 ºC in a microaerobic atmosphere. Detection level Campylobacter: 20 cfu/ml

Results and discussions

ENTEROBACTEREACEAE COUNT IN SCALD WATER AND ON SKIN AFTER PLUCKING

In both lines, Enterobacteriaceae ($\log_{10}$ cfu/ml) reached an equilibrium after 1 to 2 hours of production (see Table 1), which is in line with findings of Veerkamp (1989).

The lower bacterial counts in the scalders of test line provide a reduced potential for cross contamination in this stage and a reduced potential for attachment.

The count of non-attached Enterobacteriaceae per bird decreased significantly during immersion scalding, as illustrated by the comparison of estimated input count and output count.

Input: initial count of Enterobacteriaceae of $\log_{10}$ cfu/bird = 7.5 (Lillard 1990, Heemskerk 1991). Output: per bird 200 ml of adherent scald water. $\log_{10}$ cfu/ml = 3.84, so $\log_{10}$ cfu /bird = 6.14.

This reduction of 1.36 log unit is in line with earlier findings (Humphrey 1984, Izat 1988, Veerkamp 1989) and illustrates the washing effect of the immersion scalder.

CAMPYLOBACTER COUNT IN SCALD WATER AND ON SKIN AFTER PLUCKING

Generally, the Campylobacter counts in the scald water in both tanks remained below the detection level ($\log_{10} \leq 1.3$ cfu/ml = ≤ 20 cfu/ml).

Corresponding skin samples after plucking showed average Campylobacter counts of:

$\log_{10}$ cfu/g = 3.21(= 1620 cfu/g) in the test line;

$\log_{10}$ cfu/g = 3.71(= 5130 cfu/g) in the reference line (see Table 2).

It is interesting to note that, in all 4 tests. (Table 1) at t = 0, the scald water was only marginally contaminated with Enterobacteriaceae, but the counts on the skin after plucking were similar to the counts during the rest of the day. This indicates that the bacterial quality of the scald water was not the primary cause of Enterobacterial contamination of the skin after plucking, so hygienic scalding does not necessarily affect the products post plucking, not even after a proper feed withdrawal time of around 11 hours.

These findings suggest that the presence of Campylobacter on the skin after plucking, is primarily caused by the release of faeces during plucking, also after a feed withdrawal time of around 11 hours. The results are also in line with findings of Oosterom (1983), Genegeorgis (1986), Izat (1988), Musgrove (1997) and Berrang (2001).

The intervention may provide a basis for decontamination, as decontamination only results in a low incidence of Salmonella on decontaminated products, if initial counts were already low.

Furthermore, this early intervention has the advantage that faecal bacteria are physically removed before they have the opportunity to attach to the skin, and become more or less protected against thermal, physical or chemical treatments.

It is concluded that the described intervention contributes to less faecal contamination during primary processing, to lower counts of Enterobacteriaceae and Campylobacter in the scald water and on the skin after plucking. The intervention should therefore be considered as a part of Good Manufacturing Practice.

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Table 1 Enterobacteriaceae in scald water, and on breast skin after plucking.

		scald tank water (log10 cfu/ml)				skin, after plucking (log10 cfu/g)	
test	prod.	first tank		second tank			
#	(h.)	test	ref.	test	ref.	test	ref.
1	0	1.40	0.95	-0.30	1.34	3.60	4.30
	1	3.81	4.72	2.36	3.58	3.45	3.78
	2	4.18	4.98	3.18	4.08	3.28	3.82
	3	4.53	5.48		4.11	3.62	4.27
	4	4.41	4.71	3.81	5.20	3.55	4.09
	8	4.43	4.64	3.38	3.81	3.50	4.41
	mean	**4.27**	**4.91**	**3.18**	**4.17**	**3.50**	**4.11**
	Δ log	**0.64 (p<0.01)**		**0.99 (p<0.01)**		**0.61 (p<0.01)**	
2	0	0.30	-0.3	-0.30	-0.30	3.74	3.93
	1	4.64	4.75	3.15	3.22	3.82	3.93
	2	4.72	5.03	3.76	4.04	3.73	3.87
	3	4.55	4.98	3.58	4.04	3.62	3.95
	4	4.85	5.18	4.08	4.41	3.93	3.90
	8	4.10	4.89	3.08	3.45	3.32	3.76
	mean	**4.57**	**4.97**	**3.53**	**3.83**	**3.69**	**3.89**
	Δ log	**0.40 (p < 0.01)**		**0.30 (p < 0.01)**		**0.20 (p < 0.01)**	
3	0	1.99	0.84	0.00	-0.30	3.80	4.31
	1	3.76	4.18	2.97	2.90	3.60	4.04
	2	3.77	4.29	3.04	3.40	3.62	3.82
	3	4.37	4.76	3.53	3.73	3.56	3.83
	4	4.60	4.80	3.77	3.94	3.56	3.86
	8	3.30	3.30	2.44	3.32	3.71	4.30
	mean	**3.96**	**4.27**	**3.15**	**3.46**	**3.64**	**4.03**
	Δ log	**0.31 (p < 0.01)**		**0.31 (p < 0.01)**		**0.39 (p < 0.01)**	
4	0	2.13	0.15	0.30	-0.3	3.72	4.30
	1	3.84	4.72	2.64	2.97	3.50	3.62
	2	4.05	4.51	3.29	4.05	3.68	3.66
	3	3.74	4.71	3.26	3.84	3.41	3.72
	4	3.97	4.86	3.28	3.89	3.56	3.70
	8	3.95	3.71	2.82	4.74	3.57	4.16
	mean	**3.91**	**4.50**	**3.06**	**3.90**	**3.57**	**3.86**
	Δ log	**0.59 (p<0.01)**		**0.84 (p<0.01)**		**0.29 (p<0.01)**	
Overall	**mean**	**4.18**	**4.66**	**3.23**	**3.84**	**3.60**	**3.97**
	Δ log	**0.48 (= - 67%)**		**0.61 (= - 75%)**		**0.37 (= - 57%)**	
	p	**P < 0.01**		**P < 0.01**		**P < 0.01**	

Table 2 Campylobacter in scald water. and on breast skin after plucking.

		scald tank water (log10 cfu/ml)				skin.after plucking (log10 cfu/gr)	
test	prod.	first tank		second tank			
#	(h.)	test	ref.	test	ref.	test	ref.
1 (*1)							
2 (*2)	8	2.60	2.78	< 1.3	< 1.3	2.50	3.25
	mean	**2.60**	**2.78**	**< 1.3**	**< 1.3**	**2.50**	**3.25**
	Δ log	**0.18 (p<0.05)**				**0.75 (p<0.01)**	
3	0	< 1.3	< 1.3	< 1.3	< 1.3	2.00	3.69
	1	< 1.3	< 1.3	< 1.3	< 1.3	3.76	3.90
	3	< 1.3	**2.73**	< 1.3	**2.73**	3.59	3.70
	4	< 1.3	< 1.3	< 1.3	< 1.3	3.66	3.67
	8	< 1.3	< 1.3	< 1.3	< 1.3	3.76	4.07
	mean	**< 1.3**	**< 1.54**	**< 1.3**	**< 1.54**	**3.35**	**3.81**
	Δ log					**0.46 (p<0.01)**	
4 (*1)							
Overall	**mean**					**3.21**	**3.71**
	Δ log					**0.50 (= - 68 %)**	
	p					**p<0.01**	

*1: No Campylobacter-positive flocks available during this day: no Campylobacter tests.
*2: One Campylobacter-positive flock. at 8 hours after start production