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www.ufaw.org.uk

Animal Welfare 2013, 22: 79-84
ISSN 0962-7286
doi: 10.7120/09627286.22.1.079

The effect of pre-stun shocks in electrical water-bath stunners on carcase and meat quality in broilers

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Abstract

The objective of this study was to identify the extent of pre-stun shocks in a commercial broiler processing plant and to collect any evidence of their effect on broiler carcase and meat quality. The results showed that the degree of bird movement on entry to the water-bath was related to the incidence of pre-stun shocks, with heavier male birds showing less movement and correspondingly lower levels of pre-stun shocks. In a separate trial, 500 birds identified as receiving a pre-stun shock were compared with 500 control birds (no pre-stun shock). They were assessed for carcase downgrading conditions, red wing tips, wing haemorrhages, shoulder haemorrhages, breast muscle haemorrhages, the incidence of broken pectoral bones and also for meat quality defects. All downgrading conditions were subjectively assessed using photographic standards. The results of this study have shown that the incidence of pre-stun shocks has a significant effect both on carcase downgrading conditions and on meat quality. Pre-stun shocks are preventable and the poultry processing industry can improve both bird welfare and carcase and meat quality by ensuring that they do not occur.

Keywords: *animal welfare, carcase quality, electrical stunning, miss-stun, pre-stun shocks, water-bath stunner*

Introduction

The Council Regulation on the protection of animals at the time of killing (1099/2009) specifies in Annex I, no 3 that for the water-bath stunning of poultry, a key parameter is the prevention of electrical shocks before stunning. If a bird's leading wing or any other part of the bird makes contact with the live water before the head, the bird will receive a potentially painful pre-stun shock (PSS). Therefore, bird welfare will be compromised and it is likely that there will be an effect on carcase and meat quality through repeated electrical stimulation of the live bird in the water-bath. Terlouw *et al* (2008) reported that PSS are painful to the bird and could also stimulate birds to fly the water-bath and as a result they would not be stunned. Miss-stun can occur particularly with small birds, when they arch their neck or lift up when stimulated by a pre-stun shock and fly the full length of the water-bath stunner without being stunned. The Farm Animal Welfare Council (FAWC 2009) also reported that PSS must be painful. The occurrence of PSS in electrical water-bath stunners has been reported for many years (Wotton & Gregory 1991; Raj & Tserveni-Gousi 2000; Wotton & Wilkins 2004; HSA 2006). This welfare problem has not been prioritised by the poultry industry and it is proposed that if a link can be demonstrated between PSS and the incidence of downgrading conditions then financial pressure can be added to the welfare leverage.

Pre-slaughter stunning means any intentionally induced process, which causes loss of consciousness and sensibility without pain, including any process resulting in instantaneous death (Council Regulation 1099/2009). The stunning method employed must produce immediate loss of consciousness that lasts until death (WASK 1995) so that the bird cannot feel any pain or distress associated with the slaughter process. The most widely employed stunning method for the commercial stunning of poultry is electrical water-bath stunning. Electrical water-bath stunning of poultry is designed to pass the head and upper part of the bird through an electrically live water-bath whilst the circuit is completed through an earthed shackle. However, because the electrical current passes through the whole body of the bird, it can also affect carcase and meat quality (Wilkins *et al* 1998). Therefore, assessment of both the electrical stunning parameters and carcase and meat quality are essential requirements in order to maintain both bird welfare and profitability during the processing of poultry (Prinz 2009). Birds should be stunned through a single continuous immersion in the live water without receiving PSS (WASK 1995).

The construction of an electrically isolated entry ramp over the entrance to the water-bath will help project the head of the bird into the 'live' water quickly and reduce the incidence of PSS. The overflow of water from the water-bath stunner should leave the water-bath at the bird exit, not the entry, to reduce the incidence of pre-stun shock by preventing electrical contact through a wet route on the entry ramp. The design of the entry ramp should enable birds to be held back by the top lip of the ramp such that when they are conveyed over the lip, they enter the live water in one swift movement, preventing the incidence of PSS (Wotton & Gregory 1991).

PSS not only compromise bird welfare but can also influence carcase downgrading and meat quality (Wotton 2000). Carcase downgrading conditions have been observed in broilers, where struggling on the killing line, indicative of a reaction to an electric shock, has occurred and resulted in a large number of broilers exhibiting haemorrhaging in the thigh muscles (Wilson & Brunson 1968). Wotton and Wilkins (2004) have also reported that PSS can contribute to the incidence of carcase downgrading conditions and haemorrhaging in the musculature. Liao *et al* (2009) reported that minimising neighbouring bird interference and the incidence of PSS can effectively reduce the struggling of ducks during electrical water-bath stunning, which significantly reduced the number of carcase downgrading conditions. They also showed that wing flapping in ducks at the water-bath entrance was significantly reduced when overflow was prevented at the entry to the water-bath and that this improvement resulted in a significant reduction in the incidence of red wing tips. Hindle *et al* (2010) reported that multi-bird electrical water-bath stunner deployment does not induce effective stunning and technical adjustments of stunning parameters can result in detrimental effects on meat quality. They suggested that future European legislation should consider the following stunning parameters: (i) waveform; (ii) relationships between frequency and current allowing for individual impedence variation; and (iii) the effect of electrical water-bath stunning on meat quality, whilst still protecting animal welfare.

Therefore, bird welfare can be improved through the prevention of PSS and, in addition, the link between bird welfare and carcase and meat quality is likely to result in an increase in downgrading conditions when PSS are more prevalent. This research was instigated to determine the strength of the link between welfare and quality in order to promote the prevention of PSS in multi-bird electrical water-bath stunners.

Materials and methods

Two separate observational studies of commercial practice are described, which were carried out during normal broiler processing in a commercial plant over a two-week period. Ross-bred cockerels and pullets were used in the trials, aged from 34 to 48 days, with a range in cockerel live weights from 3.12–3.55 kg and a range in pullet live weights from 1.8–2.13 kg. The cockerels and pullets were processed on similar but separate processing lines, where the line speed for cockerels was 6,400 birds h^{-1} and, for pullets, 9,000 birds h^{-1}.

Study 1

A subjective assessment of the incidence of PSS was undertaken at the entrance to the electrical water-bath stunners on both lines. The observation position selected for Study 1 was situated directly opposite the entrance to the water-bath from where bird activity could be clearly observed. Study 1 was designed to investigate the expression of PSS and to produce categorical descriptors that would enable both the incidence and reaction of a bird to a PSS to be recorded simultaneously.

Consequently, categories of no PSS, repeated contractions due to PSS and flight triggered by PSS were determined, where:

• No PSS (noPSS) = an uninterrupted entry into the water-bath where only a single contraction of the skeletal muscles occurred;

• Repeated contractions due to PSS (cPSS) = two to four separate contractions in response to electrical stimulation (indicative of physical reactions to PSS); and

• Flight triggered by PSS (fPSS) = the bird flies the first stage of the water-bath for ≥ 4 s (indicative of an increased reaction to PSS).

The categories were used to record the incidence and reaction to PSS on both processing lines (n = 19,200 cockerels; n = 27,000 pullets). A range of bird types and sources were observed from different flocks, ages, size/weight, transport duration, time spent in lairage, time of day processed and processing line speed were examined. The number of birds that received a PSS per hour during commercial processing was calculated from the data.

Study 2

Study 2 was designed to assess the effect of PSS on carcase and meat quality in broilers. A total of 500 birds, identified as having received a cPSS or fPSS were tagged and the subsequent tenth bird on the shackle line following each tagged bird was selected as a control (noPSS) (n = 500). A single observer identified the birds that had received a PSS (category cPSS or fPSS) and spray-marked the plumage with a blue, food safety dye while the bird was within the water-bath stunner. Subsequently, each marked bird was tagged with a fluorescent orange cable-tie around the hock following neck cutting.

Following electrical stunning in a multi-bird bath, birds were conveyed to the automatic killer (Simons Engineering Company, Dallas, GA, USA) and bled by a complete ventral neck cut that severed all the major blood vessels in the neck ventral to the spine and were then subsequently processed as normal within the plant. A total of 500 birds (250 tagged as treatment T and 250 as control C) were identified each day on two consecutive days (D1 and D2). The experimental birds were sampled across a number of flocks/batches of birds within the two days. The control birds were selected following evisceration when the tagged and control birds were removed from the processing line for overnight chilling.

https://doi.org/10.7120/09627286.22.1.079 Published online by Cambridge University Press

Electrical parameters

The electrical parameters used in the multi-bird water-bath stunner were recorded as seen in Table 1.

Carcase quality assessment

Following primary processing (stunning, slaughter, feather removal and evisceration) an assessment was made of both the tagged and control birds for selected aspects of external carcase quality. The downgrading conditions that were selected, which were thought likely to be affected by PSS, were red wing tips, wing haemorrhages and shoulder haemorrhages. These were assessed subjectively against standard photographic scales (Veerkamp *et al* 1987). The photographic scales were categorised from 0 (no haemorrhage) to 3 (severe haemorrhage).

Meat quality assessment

The carcases were held overnight at 4°C and filleted manually the following day. They were assessed for broken bones in the pectoral region and the major fillet (dorsal and ventral aspect) and the minor fillet (ventral aspect) were assessed for the incidence of haemorrhages. The incidence of a broken bone was assessed by palpating the pectoral region of each carcase after the fillets were removed to identify whether the coracoid and/or furculum was broken. In addition, when a break was found, investigation was undertaken to determine whether there was an associated haemorrhage. Broken bones with an associated haemorrhage indicate that the bone was broken when the bird was alive, before or during the stunning operation, and therefore did not occur as a result of post mortem machine damage. The incidence of broken bones was simply scored as absent (0) or present (1). Breaks/dislocations to the coracoid or breaks to the furculum were found on either a single side or on both sides of the carcase but in either case a score of present (1) was recorded. All downgrading conditions to the breast fillets were assessed subjectively using photographic standards (Veerkamp *et al* 1987), which were categorised from 0 (no haemorrhage) to 3 (severe haemorrhage). The protocol was repeated on the following day to assess a further 250 PSS and 250 control birds.

Statistical analysis

The data were analysed using the software package SPSS v 16.0. A Chi-squared test was used to assess whether there was an overall difference between flocks in Study 1. The relationships between the quality outcome measures and the treatment/control and day of observation in Study 2 were investigated using log-linear model selection. Log-linear model selection works by first fitting a saturated model of the cell counts, broken down by all the factors, eg minor fillet (dorsal) score by study day by treatment. At each subsequent step, the effect with the largest significance level for the likelihood ratio change is deleted, provided the change is less than $P > 0.05$, until the 'generating class' remains. The generating classes for each of the outcome variables are reported in the *Results* section.

Table 1 Electrical parameters used in the multi-bird water-bath stunner.

Parameter	Value
Number of birds in the water-bath	14
Waveform	Pulsed DC with a 30% duty cycle
Frequency	600 Hz
Applied voltage	51 volts rms
Average current per bird	71 mA (total current = 0.99 A with 14 birds in the water-bath)
Poultry stun monitor	
Dwell time	9.4 s
Current	51 mA rms per bird (resistance = 1,000 Ω therefore calculated voltage = 51 volts)

Results

Study 1

The results from the subjective assessment of PSS are shown in Table 2, which summarises the data by flock of origin, together with flock sex, age and live weight, of the count of birds within each score category. A Chi-squared test showed the scores of Flock 3 to be significantly different ($P < 0.001$) from the other flocks and the table shows them to have suffered an overall lower incidence of PSS (cPSS combined with fPSS). When the results are amalgamated into simply 'Cockerel or Pullet' and 'noPSS/cPSS or fPSS', a Chi-squared test indicated that there was a significantly higher level of PSS amongst pullets, with 9.8% categorised as cPSS or fPSS compared with only 6.9% of cockerels. When the types of PSS are analysed separately a significant association is found between both cPSS and type of bird ($P = 0.029$) with 2.9% of cockerels and 2.6% of pullets suffering cPSS. A significant association is also seen between fPSS and type of bird ($P < 0.001$) with 4.3% of cockerels and 7.6% of pullets suffering fPSS. It was also calculated that, on average, 142 pullets h^{-1} (1.6%) 'over-flew' the full length of water-bath stunner without being stunned.

Study 2

The results of the log-linear model selection analyses showed that for every outcome variable the generating class consisted of only 'PSS category' by 'Quality Score' and 'Day' by 'Quality Score'. No variable required the full generating class of 'PSS category' by 'Day' by 'Quality Score'. The results are presented as paired contingency tables, one showing the overall association between PSS category and the quality scores and another showing the association between the day of observation and the quality scores. These tables all show a significant association between the two variables at $P < 0.05$. In summary, the analysis showed that for every one of the quality outcome

Table 2 Flock-specific details and counts of the scores allocated to the birds within each of the six flocks observed.

Flock number	N	Sex	Age (days)	Average live weight (kg)	noPSS (n)	cPSS (n)	fPSS (n)	Categories (cPSS+fPSS)/total (%)
1	6,400	Cockerel	45	3.38	5,868	198	334	8.3
2	6,400	Cockerel	46	3.29	5,776	234	390	9.8
3	6,400	Cockerel	45	3.55	6,228	102	70	2.7
4	9,000	Pullet	34	1.94	8,065	170	765	10.4
5	9,000	Pullet	35	1.90	8,172	252	576	9.2
6	9,000	Pullet	34	1.92	8,109	216	675	9.9

Table 3 The effect of PSS on red wing tips and wing haemorrhages in broilers (days 1 and 2 combined).

		% birds within each red wing tip score				% birds within each wing haemorrhage score			
	N	0	1	2	3	0	1	2	3
cPSS + fPSS	478	21.7	55.6	15.4	7.1	38.7	32.0	20.7	8.5
noPSS	477	31.8	54.7	11.5	1.8	57.0	28.3	10.2	4.6

Table 4 The effect of pre-stun shocks on red wing tips and wing haemorrhages in broilers for days 1 and 2 (shocked and not shocked combined).

		% birds within each red wing tip score				% birds within each wing haemorrhage score			
	N	0	1	2	3	0	1	2	3
Day 1	480	22.9	53.7	17.7	6.2	56.6	25.0	14.3	3.9
Day 2	475	31.3	56.6	9.2	2.7	39.9	35.3	16.6	9.2

variables there was a set effect of being shocked or not which was consistent across both days, and there was also a difference in outcome quality scores between the two days (upon which the 'shocked or not' effect was superimposed). With log-linear modelling the results can be thought of as analogous to ANOVA where there are two significant main effects (day and PSS) but these are independent, ie there is no significant interaction effect.

Carcase quality assessment

Table 3 shows the percentage of birds within each of the 'red wing tip' carcase quality scores and the 'wing haemorrhage' quality scores broken down by birds, which received a PSS, and the control birds. In this table and the others below, a count of the total number of birds is also given, to allow cell-specific counts to be calculated. The variation between the number of birds per group for the carcase quality assessments (Tables 3 and 4) and for the meat quality assessment (Tables 5 and 6) was caused by primary processing line problems that were outside the control of the authors. It can be seen from Table 3 that PSS was associated with a significantly higher percentage of quality problems.

Table 4 shows the percentage of birds within each of the 'red wing tip' carcase quality scores and the 'wing haemorrhage' quality scores broken down by day of observation. It can be seen from Table 4 that day 1 was associated with a significantly higher percentage of quality problems (red wing tips). Interestingly, for haemorrhages of the wing, the pattern was reversed, with the poorer meat quality being associated with birds slaughtered on day two.

Meat quality assessment

Table 5 shows the percentage of birds within each of the four meat quality outcome variables, and the measurement scores within each, broken down by birds which received a PSS and control birds which did not. It can be seen from Table 5 that for each outcome, haemorrhage of the major fillet (dorsal), major fillet (ventral), minor fillet (dorsal) and broken or intact pectoral bone, birds which had received a PSS were associated with poorer meat quality scores in every case.

Table 6 shows the percentage of birds within each of the four meat quality outcome variables and the measurement scores within each, broken down by the day on which the observations were taken. It can be seen from Table 6 that for the outcome variables, haemorrhage of the major fillet (dorsal), major fillet (ventral) and broken or intact pectoral bone, the meat quality problems were higher on day one of the study. Interestingly, for the meat quality variable haemorrhage of the minor fillet (dorsal), the pattern was reversed, with the poorer meat quality being associated with birds slaughtered on day two.

Table 5 The association between PSS and quality scores for haemorrhages in the major fillet (dorsal and ventral aspects), minor fillet (dorsal aspect) and broken pectoral bones in broilers (days 1 and 2 combined).

		% major fillets within each haemorrhage score (dorsal aspect)				% major fillets within each haemorrhage score (ventral aspect)				% minor fillets within each haemorrhage score (dorsal aspect)				Pectoral broken bones (%)	
	N	0	1	2	3	0	1	2	3	0	1	2	3	0	1
cPSS+fPSS	500	41.4	40.0	11.4	7.2	49.0	32.8	14.0	4.2	27.4	43.4	18.2	11.0	71.8	28.2
noPSS	500	78.8	16.8	2.4	2.0	74.4	20.2	4.4	1.0	46.0	40.6	10.6	2.6	89.8	10.2

Table 6 The effect of study day on haemorrhages in the major fillet (dorsal and ventral aspects), minor fillet (dorsal aspect) and pectoral broken bones in broilers.

		% major fillets within each haemorrhage score (dorsal aspect)				% major fillets within each haemorrhage score (ventral aspect)				% minor fillets within each haemorrhage score (dorsal aspect)				Pectoral broken bones (%)	
	N	0	1	2	3	0	1	2	3	0	1	2	3	0	1
Day 1	449	50.3	36.7	7.5	5.3	59.2	29.8	8.6	2.2	39.4	44.0	12.2	4.2	77.5	22.4
Day 2	551	68.0	21.5	6.3	3.9	63.7	21.9	9.6	2.9	34.4	40.2	16.3	8.8	83.4	16.5

All scores are significantly different by $P < 0.05$ between days except major fillet ventral aspect.

Discussion

Study 1

The commercial poultry plant where the study was undertaken processed birds on two separate lines to optimise the procedures for the type and therefore size of bird, ie cockerels versus pullets. The results shown in Table 2 demonstrate that with the heavier cockerels (average weight = 3.41 kg) the level of PSS was lower than with the lighter pullets (average weight = 1.92 kg). In fact, the level of PSS for flock 3 (the heaviest birds assessed) was again significantly lower ($P < 0.05$) than for the remaining cockerel flocks. These results suggest that when heavier birds are inverted and restrained on a shackle they are physically unable to display much movement and therefore are less able to avoid a swift immersion in the water-bath. Lighter, more active birds on the water-bath entry ramp are much more likely to receive a PSS. It is recognised (anecdotally) that lighter free-range birds display considerably more movement when shackled than intensively reared broilers (S Wotton, personal observation 2012) and therefore higher levels of PSS would be expected. When the average weight of the cockerels for each flock is considered with birds of the same age, the heaviest, and probably the most immobile birds (flock 3), displayed the very lowest incidence of PSS. The significant associations seen between the two types of PSS and type of bird supports the conclusion that the heavier cockerels are much less able to fly when stimulated by PSS, whereas the lighter pullets were physically able to avoid the water following a first PSS. The incidence of miss-stunned birds was relatively small (142 pullets h^{-1}). However, legislation (WASK 1995) requires that when a water-bath stunner is used to stun birds, every bird is stunned. The missed-stun birds were conveyed to the automatic neck cutter and bled by a complete ventral neck cut that severed all major blood vessels or manually by the back-up slaughtermen with the aim of severing both carotid arteries. In both cases birds were slaughtered without stunning. This incidence of miss-stuns could be reduced if the height of the water-bath is properly adjusted and bird entry is improved.

Study 2

It has been reported (Wotton & Wilkins 2004) that both external carcase quality and meat quality can be adversely affected by electrical multi-bird water-bath stunning. The external quality assessments that were thought likely to be affected by PSS were red wing tips, wing haemorrhages and shoulder haemorrhages. The incidence of shoulder haemorrhages was low (1.8%) and did not differ significantly between the treatment and control groups. The incidence of shoulder haemorrhages was recorded as the least damaging downgrading conditions of the carcases. The meat quality assessments thought to be most likely affected and selected for this study were broken bones and haemorrhages to the major and minor fillet. All of both these carcase and meat quality variables were significantly ($P > 0.05$) and adversely affected by the occurrence of a PSS on entry to the water-bath. In every quality assessment there was always more damage in the PSS treatment group when compared with the control (noPSS group) and with every category the highest downgrading condition was with the birds that received the PSS.

Overall, there was also an effect of 'day' seen (Tables 4 and 6) on both carcase and meat quality in that there were day-to-day changes in the overall levels of carcase damage and meat quality. However, with regard to our main findings, this effect was incidental and independent of the effects of PSS. The incidence of PSS is very likely to be related to the degree of bird movement on the shackle line at the entrance to the water-bath stunner. Therefore, this movement is likely to vary due to the condition of the birds at hang-on, eg their levels of fatigue, in addition to their live weight at slaughter. Processors should expect a range in the level of PSS with resultant range in the level of downgrading unless measures are taken to prevent the occurrence of PSS with electrical water-bath stunning.

EC regulation (1099/2009) stipulates in Annex I that for electrical water-bath stunning a key consideration is the prevention of electrical shocks before stunning. The results reported here add very strong commercial and economic arguments to this legislative welfare requirement, entirely justifying any financial output that would be required to improve controlled entry of birds into a water-bath stunner through the potential for improvements in carcase and meat quality. PSS can be prevented by careful water-bath entry design and modification. It should be entirely possible to avoid PSS in commercial processing plants and there is a strong economic reason to do so.

Animal welfare implications and conclusion

Both trials have shown that the incidence of PSS remains a significant welfare problem to broiler chickens during electrical water-bath stunning. PSS not only compromise bird welfare but can have a significant effect on external carcase downgrading conditions and internal meat quality. The poultry processing industry has been encouraged to take action to eradicate this welfare problem (FAWC 2009), which is a financial burden to the industry through extra trimming, increased carcase downgrading conditions and muscle haemorrhages, with and without broken bones in the premium portion of the carcase. Eradicating the prevalence of PSS during electrical water-bath stunning will not only improve bird welfare but also contribute to maintaining the highest quality standards that are commercially required in today's market. Terlouw *et al* (2008) also identified these issues previously and reported that PSS are painful to the bird and could also stimulate birds to fly the water-bath and, as a result, they would not be stunned. Eradicating the incidence of PSS may also eliminate the problem of miss-stunned birds, which would help to improve the acceptability of electrical water-bath stunning to those who are critical of its performance.

Acknowledgements

This research was supported by a grant (Dorothy Sidley Memorial Scholarship) from the Humane Slaughter Association (HSA). The authors also wish to thank Federica Monte and staff at the poultry processing plant for valuable assistance during the trials.

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