The effects of pre-slaughter restraint (for the purpose of cattle identification) on post-slaughter responses and carcass quality following the electrical stun/killing of cattle in a Jarvis Beef stunner

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Abstract

This study compared normal post-Jarvis stun/kill responses and carcass quality with those occurring when crush restraint was not used during pre-slaughter. The carcasses of 1065 cattle slaughtered during one week at a commercial abattoir were evaluated for quality. The post-stun/kill responses of 788 of these animals were also assessed. An additional study of data from the carcasses of 6601 cattle was further evaluated for quality findings. A significant reduction in post-stun/kill limb movement, muscle tone and the expression of brainstem functions was recorded when restraint was not used. Abolishing crush restraint pre-slaughter also produced a significant reduction in the incidence of blood splash. In addition, the study also showed that animal identification post-slaughter could be successfully implemented with no negative consequences to food safety or traceability. It is suggested that abolishing the use of pre-slaughter crush restraint of cattle would enhance animal welfare and operator safety in plants whether electrical, or mechanical stunning was employed.

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1. Introduction

The loss of value during the marketing of cattle has traditionally been associated with injuries, dark cutting beef and losses through bruise-related carcass trimming and downgrading (Warriss, 1990). These consequences mainly relate to exertions and handling, hours or days before slaughter. Ferguson and Warner (2008), suggest that the impact of acute handling stress in cattle may be underestimated. During delivery to the point of stun, cattle inevitably experience a degree of stress associated with movement in a confined and novel race system. Even with optimum stockmanship and race design, the level of stress is likely to increase with any additional animal manipulation. UK animal identification procedures based on The Cattle Passport Order of 1996, require the matching of age (as estimated from the teeth), gender and ear-tag numbers with individual cattle passports that involve physical crush restraint and further human interaction. The purpose of these procedures was primarily to ensure traceability and identification in the wake of the Bovine Spongiform Encephalitis (BSE) crisis, providing assurances to consumers regarding the safety and origin of their meat (Mitchell et al., 2005). It has been suggested that crush restraint and handling of animals prior to slaughter have led to an overall reduction in the welfare of cattle in abattoirs within the UK (Gregory, 2008). Studies of hormonal responses to handling suggest cattle subjected to unpleasant stimuli are reluctant to repeat the experience. It has also been confirmed that animals which find handling aversive maintain a negative response over time, suggesting that the most fractious animals at the crush will also be difficult to coerce into the stun box, which is similarly restrictive (Grandin, 1993). This prior experience may result in animals which are even more reluctant to enter the Jarvis Beef Stunner and excessive coercion may be required under these circumstances, further compromising the welfare of cattle at slaughter.

Electrical stun/kill using the Jarvis Beef Stunner has been introduced into a few UK plants (n = 7) as an alternative to standard mechanical systems. The key welfare advantage with the Jarvis Beef Stunner is the inclusion of a cardiac arrest cycle, which through the induction of ventricular fibrillation via the passage of current from a nose-contacting electrode to a pneumatically lifted brisket contact, promotes the beginning of death to the point of stun (Wotton, Gregory, Whittington, & Parkman, 2000). Successful application stops circulation, making recovery impossible; whereas following captive-bolt stunning some animals may still remain conscious or regain consciousness making the timing and accuracy of the sticking procedure an important consideration in welfare terms (Weaver & Wotton, 2009). Fundamental to the function of the automated Jarvis Beef Stunner is head restraint through a pneumatic chin...
lift following the application of a neck yoke ensuring electrical contact with the nose-plate electrode. The neck yoke also serves as an electrode contact during the passage of a head-only stunning current which passes transcranially, to induce an electroplastic seizure that stuns the animal, preceding ventricular fibrillation (Wotton et al., 2000). To reduce post-stun convulsions a spinal depolarisation current is applied between the nose-plate and the rear of the animal, where it makes contact with the box, and constitutes the last of the 3 cycles prior to ejection and hoisting.

The expectation following an electrical stun/kill with the Jarvis Beef Stunner is a fully relaxed carcass exhibiting no muscle tone with little, if any, movement after the stun. The situation may be less clear if the spinal discharge cycle has not been fully effective as spinal reflex activity can cause a great deal of movement (Blokhuys et al., 2004). Additionally, the primitive brain stem will generally outlive higher centres’ following cardiac arrest, potentially maintaining rhythmic breathing and gasping, whilst palpebral and corneal reflexes may remain intact for a period after cortical and mid-brain anoxic death (Wotton et al., 2000).

The passage of electrical current through animal tissue presents some inevitable quality consequences with the formation of haemorrhages within primal hindquarter cuts, as well as broken bones that may result from the simultaneous maximal contraction of normally opposing muscles groups (Daly, 2005). With the low frequency waveforms (50 Hz), typically in use with the Jarvis Beef Stunner, stimulation of the peripheral motor neurons, as well as direct stimulation of muscle fibres and motor areas in the brain, may all result in muscle contraction with resulting capillary rupture (with subsequent blood splash/haemorrhage), due to the nature of muscle contractile forces (Gregory, 1998). Similarly, bone breaks (typically femoral fractures), may occur due to these maximal and non-physiological contractions.

Cattle subjected to pre-slaughter crush restraint are likely to be more stressed at the point of stun. Fractious animals may attempt to avoid entering the Jarvis Beef Stunner and it may take longer to capture the head with the neck yoke mechanism. In addition to compromising operator safety, stressed cattle are likely to affect stunning efficiency (a welfare issue) and potentially lead to sub-optimal meat quality. Furthermore, animals may exhibit differences in the physical signs immediately post-stun/kill.

The aim of this study was to determine how pre-slaughter crush restraint, used for the purpose of cattle identification, affects carcass characteristics post-stun/kill. In particular, how it will affect post-kil reflexes and movement, as well as the incidence of carcass and meat quality defects. Product quality issues, such as blood splash, found following electrical stun/kill of cattle are cited as major drawbacks against the use of the Jarvis Beef Stunner (Gregory, 2005). The objective was to discover whether a potentially simple change could save the meat industry losses to prime product. Moreover, potential improvements in the welfare of the animals and safety of operatives who work with cattle immediately prior to and following the stun/kill would also be of value. Such improvements would add to the case supporting the Jarvis stun-box as a safe, high welfare, and good carcass and meat quality alternative to mechanical stunning systems.

2. Materials and methods

2.1. Experiment 1

Cattle destined for slaughter in a commercial abattoir were assigned to one of two treatments:

- Treatment 1 — animals that were exposed to crush-restraint prior to slaughter (n = 466);
- Treatment 2 — animals where no crush-restraint was used prior to slaughter (n = 208).

Treatment 1 (T1) utilised the standard UK commercial practice, where cattle where held within a crush before stunning, in order to confirm their identity prior to slaughter. Their identity was determined by checking their breed, age, and that both ear-tags had numbers matching the corresponding cattle passport. This involved restraint and human interaction including physical contact to read ear-tags. Following derogation from the Food Standards Agency (FSA), animals for Treatment 2 (T2) were moved through the same race but without crush-restraint; however, an initial identification was made by matching at least one ear-tag to the cattle passport. This was possible with no physical contact between the stockman and the animal. Positive confirmation of identity was delayed to a post-mortem check on the slaughter-line, after bleeding, when all the standard identification checks were conducted. Any carcasses with information that did not match were removed from the food chain following normal carcass condemnation procedures. A range of parameters was recorded from all experimental carcasses in both treatments, post-stun/kill, as described below (see the Assessment of carcasses post-stun/kill section).

2.1.1. Slaughter and processing of animals

The experiment was conducted over a four-day period, within a commercial red meat abattoir, with an average throughput of 1500 cattle per week (300 per day). Animals which were exposed to long journeys were laired overnight for up to 16 h, with a minimum lairage time of one hour for animals sourced locally. When cattle were required for slaughter, they were moved from pens through a series of gates that allowed for a sequential release of animals into a circular crowd pen with minimal disruption to the remaining cattle in the lairage. A moving gate in the crowd pen allowed lairage operatives to passively move animals into the race. The race incorporated a standard crush where T1 cattle were held, in line to allow normal identification procedures to be carried out prior to movement to the point of stun. Non-return gates in conjunction with elevated catwalks beside the race enabled abattoir staff to maintain cattle movement. Individual animals were driven into the stunning box and a guillotine-type, non-return gate descended, restraining the animals in the Jarvis Beef Stunner. When each animal was in an appropriate position, the Jarvis Beef Stunner was activated and the pneumatic neck yoke (with associated electrodes) applied. This restrained the head of the animal. Then a chin-lift moved vertically, lifting the head, to allow contact with a nose plate electrode. An extended pneumatic brisket electrode was applied between the forelimbs of each animal to make electrical contact with the brisket. Water was applied to the electrodes to improve electrical conductivity. Subsequently, a head-only stunning current was applied for four seconds, between the nose plate and neck yoke electrodes. Following this application, a 23 second current application was applied between the nose plate and brisket electrode to induce ventricular fibrillation (the cardiac arrest cycle). A spinal depolarisation cycle applied between the nose plate electrode and the rear of the animal where it made contact with the Jarvis stun-box was applied for five seconds. Sinusoidal AC at 50 Hz was applied for all three cycles, with the voltage limited to allow for a maximum current of approximately 3.5 A via a voltage-limiting choke. The parameters described were applied unaltered, for the duration of the study.

2.1.2. Experimental animals

1065 cattle slaughtered during the week were evaluated for carcass quality and 788 of these animals were specifically assigned a treatment to assess post-slaughter responses. The study included 144 bulls, 244 heifers and 400 steers from 63 producers; 29 different breeds were present according to their cattle passport records. The mean carcass weight was 359.1 kg (SD ± 54.1). To enhance the meat quality investigation, a further 277 carcasses slaughtered within the same week were examined as described below (see the Assessment of carcasses/meat quality section).
2.1.3. Assessment of carcasses post-stun/kill
Following the procedure previously described, cattle ejected from the Jarvis Beef Stunner were examined by two researchers, the first assessing animals on a restraining cradle immediately following rollout and a second following shackling and hoisting at the point of sticking. Each researcher recorded respiratory activity, limb movement, muscle tone, eye-roll, palpebral and corneal reflexes for all animals and, in addition, the overall physical response of each animal was subjectively assessed. The assessment protocols were as follows:

a. Respiratory activity: Three or more breaths, as assessed visually, were classified as rhythmic breathing, whilst gasping was similarly determined when up to two breaths were visible.

b. Limb movement: It was recorded as present when either moderate or severe activity was observed. At the point of stick, this was recorded ≤ 2 min.

c. Muscle tone was evaluated by visual examination of the tail, ears and tongue. It was recorded to be present when tone was evident.

d. Eye roll: was recorded to be present when the eyeball rotated or moved.

e. A positive palpebral reflex recorded when the response was elicited by contact with the medial or lateral canthus of either eye.

f. A positive corneal reflex recorded when response was elicited by contact with the eyeball.

All the above were recorded as

0 — absent;
1 — present.

In addition, the researcher at rollout also recorded the time between stunning and exsanguination, using a stopwatch, (stun-to-stick interval).

2.1.4. Assessment of carcass/meat quality
Following chilling, carcasses were quartered, deboned and processed following the normal abattoir routine. A record was kept of the presence of broken femurs, and the occurrence of petechial haemorrhaging (blood splash) in hindquarter primals, including the sirloin, rump and silverside.

2.2. Experiment 2
A secondary study focused exclusively on the carcass quality implications of the use of the crush restraint pre-slaughter. A review of data collected from over six thousand carcasses, (n = 6061) was conducted following either T1 (n = 3032) or T2 (n = 3029), where the incidence of blood splash and broken bones were assessed in the hindquarter.

2.3. Statistical analysis
Data was analysed statistically using the software package SPSS (v19 IBM SPSS Inc). Chi-square tests were used to compare proportions of animals exhibiting the various responses at rollout and at sticking. An Independent sample t-test was used to compare the mean stun-to-stick intervals of each treatment. Chi-square tests were also used to compare the incidence of carcass defects between T1 and T2.

3. Results

3.1. Experiment 1

3.1.1. Statistical analysis
114 records were not used for post-stun/kill responses in Experiment 1, as a problem was identified with the brisket electrode that could potentially influence the results. For the quality assessment, the entire day’s kill was discarded.

3.1.2. Post-stun/kill responses at rollout
There was a highly significant reduction in the presence of muscle tone when crush restraint was not used (p < 0.001). Similarly, rhythmic breathing and rotation of the eyeball (eye roll) were also significantly reduced (p < 0.001 and p < 0.004 respectively). The presence of gasping (p = 0.479), palpebral reflex (p = 0.697), and corneal reflex (p = 0.940) did not differ significantly when measured on the cradle (Table 1); however, the difference in limb movements (p = 0.073), when measured on the cradle were close to significance.

3.1.3. Stun-to-stick interval
In total 10 cattle were excluded due to captive bolt use as they fell in the box in positions which made ejection and subsequent sticking difficult or were struggling excessively at the point of stun, there was no treatment effect. The remaining recordings were statistically analysed using an independent sample t-test. No significant difference was found in the mean stun-to-stick intervals between the two treatment groups (p = 0.645). The mean (±SD) was 50.13 (±7.9) seconds and 50.42 (±6.9) seconds for Treatment 1 and Treatment 2 respectively.

3.1.4. Post-stun/kill responses at sticking
There was a highly significant reduction in limb movement at sticking when crush restraint was not used (p < 0.001). Muscle tone was also reduced to a level bordering on statistical significance and the results for breathing, gasping, eye roll, palpebral reflex and corneal reflex did not differ significantly (Table 2).

3.1.5. Blood splash/petechial haemorrhaging
During this study, the only recorded incidences of blood splash were in the rump (Gluteus medius), and silverside (primarily the Biceps femoris). The amount of blood splash in the rump was significantly reduced when cattle were not held in a crush (p = 0.024), whilst in the silverside, (p = 0.186) there was no statistical difference, (Table 3). No blood splash was found in the topside, silverside, rump, fillet (M. psoas major), striploin (M. longissimus dorsi), and flank; however as there was no incidence after Treatment 2, statistical analysis was not conducted for the striploin or flank. The reduction in overall levels

Table 1: The effect of experimental treatment on animal responses at rollout.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Pearson’s Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Percentage of animals exhibiting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breathing</td>
<td>42.1</td>
<td>28.8</td>
</tr>
<tr>
<td>Gasping</td>
<td>19.1</td>
<td>16.8</td>
</tr>
<tr>
<td>Limb movement</td>
<td>34.3</td>
<td>27.4</td>
</tr>
<tr>
<td>Muscle tone</td>
<td>12.9</td>
<td>3.4</td>
</tr>
<tr>
<td>Eye roll</td>
<td>41.7</td>
<td>30.3</td>
</tr>
<tr>
<td>Palpebral reflex</td>
<td>8.6</td>
<td>7.7</td>
</tr>
<tr>
<td>Corneal reflex</td>
<td>18.0</td>
<td>18.3</td>
</tr>
</tbody>
</table>

Treatment 1 refers to ‘crush restraint for identification’ and Treatment 2 refers to ‘no crush restraint’.

Significant differences were determined by partitioning into 2 x 2 Chi-square tests.
The range of responses seen in cattle following the use of the Jarvis Beef Stunner is diverse and includes a range of brainstem, as well as spinally mediated, expressions. In this study the signs were evaluated both at rollout and at sticking.

There was a significant reduction in limb movement at sticking when no restraint was applied pre-slaughter. Coupled with this response in muscle tone at rollout, the reductions may suggest that animals entering the Jarvis Beef Stunner with less prior agitation make better contact with the rear of the box during the spinal discharge cycle, allowing for improvements in the spinal discharge process. Additionally, limb movement at rollout (p = 0.073) and the muscle tone at sticking (p = 0.05) exhibited reductions, which were close to statistical significance (p < 0.05). The expectations of the operatives of the hoist, tacitly, less excited animals could have undergone reduced basal blood pressures at stun/kill; thereby exhibiting fewer ruptures of blood vessels and therefore haemorrhages within the musculature following the contractile forces generated by electrical stunning.

Improvements in blood splash could be associated with reduced levels of agitation in cattle entering the Jarvis Beef Stunner, when crush handling is not used. Tactically, less excited animals could have reduced basal blood pressures at stun/kill; thereby exhibiting fewer ruptures of blood vessels and, therefore, haemorrhages within the musculature following the contractile forces generated by electrical stunning.

### 4.3. Broken bones and crush restraint

Another consequence of the maximal contractile forces generated by electrical stunning is broken bones. Typically, the large muscles of the eyeball that may also be present following electrical stun/kill. It has been suggested that, during the electrical stun/kill of cattle, the higher cortical centres are more susceptible to anoxia induced by associated circulation failure, and residual brainstem activity allows for breathing and eyeball rotation (Wotton et al., 2000). Less agitated cattle may improve brisket contact, thereby allowing ventricular fibrillation, cardiac arrest and therefore brainstem death to occur earlier. However, there is an expectation for anything affecting brainstem function to also impact corneal and palpebral reflexes, both of which are modulated by cranial nerves originating in the brainstem. The order in which brainstem functions are lost during brain death has not yet been investigated, so some functions could outline others.

### Table 2

<table>
<thead>
<tr>
<th>Percentage of animals exhibiting</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
<th>Pearson's Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breathing</td>
<td>22.5</td>
<td>19.6</td>
<td>0.70</td>
<td>0.399</td>
</tr>
<tr>
<td>Gasping</td>
<td>36.2</td>
<td>35.4</td>
<td>0.04</td>
<td>0.845</td>
</tr>
<tr>
<td>Limb movement</td>
<td>26.3</td>
<td>13.9</td>
<td>12.87</td>
<td>0.000</td>
</tr>
<tr>
<td>Muscle tone</td>
<td>12.6</td>
<td>7.7</td>
<td>3.63</td>
<td>0.050</td>
</tr>
<tr>
<td>Eye roll</td>
<td>16.7</td>
<td>12.9</td>
<td>1.56</td>
<td>0.203</td>
</tr>
<tr>
<td>Palpebral reflex</td>
<td>10.3</td>
<td>8.6</td>
<td>0.46</td>
<td>0.496</td>
</tr>
<tr>
<td>Corneal reflex</td>
<td>4.1</td>
<td>4.8</td>
<td>0.18</td>
<td>0.674</td>
</tr>
</tbody>
</table>

Treatment 1 refers to ‘crush restraint for identification’ and Treatment 2 refers to ‘no crush restraint’. Significant differences were determined by partitioning into 2 × 2 Chi-square tests.

### Table 3

<table>
<thead>
<tr>
<th>% Blood splash rump</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
<th>Pearson's Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.7</td>
<td>4.4</td>
<td>4.98</td>
<td>0.024</td>
</tr>
<tr>
<td>% Blood splash silverside</td>
<td>7.1</td>
<td>5.2</td>
<td>1.73</td>
<td>0.186</td>
</tr>
<tr>
<td>% Broken bones</td>
<td>1.2</td>
<td>5.2</td>
<td>13.61</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Treatment 1 refers to ‘crush restraint for identification’ and Treatment 2 refers to ‘no crush restraint’. Significant differences were determined by partitioning into 2 × 2 Chi-square tests.

### Table 4

<table>
<thead>
<tr>
<th>% Blood splash</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
<th>Pearson's Chi-square</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topside</td>
<td>1.9</td>
<td>0.3</td>
<td>38.25</td>
<td>0.000</td>
</tr>
<tr>
<td>Silverside</td>
<td>8.5</td>
<td>4.4</td>
<td>42.59</td>
<td>0.000</td>
</tr>
<tr>
<td>Rump</td>
<td>7.8</td>
<td>3.3</td>
<td>50.83</td>
<td>0.000</td>
</tr>
<tr>
<td>Fillet</td>
<td>0.8</td>
<td>0.2</td>
<td>10.00</td>
<td>0.001</td>
</tr>
<tr>
<td>Total</td>
<td>19.7</td>
<td>8.4</td>
<td>159.34</td>
<td>0.000</td>
</tr>
<tr>
<td>% Broken bones</td>
<td>1.6</td>
<td>1.7</td>
<td>0.10</td>
<td>0.757</td>
</tr>
</tbody>
</table>

Treatment 1 refers to ‘crush restraint for identification’ and Treatment 2 refers to ‘no crush restraint’. Significant differences were determined by partitioning into 2 × 2 Chi-square tests.
4.4. Animal welfare implications

Whilst further behavioural research may allow a better understanding of some of the reasons behind the findings in this study, the potential benefits of improving the accuracy of the shock during mechanical stunning may also be worth further investigation. If cattle are less excitable at the point of stun, accuracy and efficiency could potentially improve. In the UK, retailers have applied pressure on FBOs to significantly restrict the use of electrical goads on livestock at the abattoir. Therefore, a methodology that reduces the stress that cattle are exposed to, by enabling less coercion when moved into the stun box, should be encouraged. Research into the currents, frequencies and waveforms used during electrical stunning could allow for more effective spinal depolarisation with less direct muscle stimulation that could further improve the quality of the ultimate product, which would encourage its use.

5. Conclusions

Considering the massive implications of product quality to the profitability of an abattoir, the exclusion of pre-slaughter crush restraint can be a simple first step to improving product quality by lowering blood splash in the primal product where electrical stunning is in use. Working to restrain fractious cattle is also potentially harmful for operatives therefore removing the process would aid their safety. Potential reductions in carcass movement can also improve the safety of abattoir employees. The operation of the pre-slaughter crush restraint is also a welfare concern particularly if more coercion is required to move animals into the Jarvis Beef Stunner following this form of restraint. The Food Business Operator (FBO) could conduct effective identification post-kill without compromising food safety, as failed identity checks can display rhythmic breathing movements following or before sticking. Electrically stunned pigs can display corneal reflexes (Vogel et al., 2011). Therefore, positive brain-stem activity can be seen with these systems in animals that are clearly dying.

The presence of eye reflexes whether corneal or palpebral is brain stem in origin arising through the 5th cranial (afferent) and 7th cranial (afferent) nerves and indicates function at a sub-cortical level (Scagliotti, 1999). The use of a cardiac arrest stunning system with cattle (Wotton et al., 2000) demonstrated that there was sometimes a resumption of the eye reflexes, first the corneal, then the palpebral reflexes following a cardiac arrest stun. However, these responses were lost subsequently and brain death occurred without the resumption of consciousness. It is probable that the mid-brain and cortex, which succumb to anoxia faster following cardiac arrest than the brain-stem region (control of brain-stem reflexes), initiate the end of global epileptiform activity in the brain. These higher centers, which are necessary for consciousness, die first, but the more resistant brain-stem region survives longer. However, this hypothesis has not been proved with stunning systems that induce a cardiac arrest.

Acknowledgements

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