Effect of different stunning voltages on blood loss, carcass quality and breast muscle pH

Effekt verschiedener Voltzahlen bei der Betäubung auf Blutverlust, Schlachtkörperqualität und pH des Brustmuskels

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Introduction

Present poultry regulations state that inadequate blood removal from poultry justifies either lower grades or condemnation of the carcasses unfit for human consumption. Excessive blood in deeper tissues is objectionable because it may separate out during cooking or, if it is trapped within, may cause brownish discoloration. Both of these effects are undesirable to the consumer because blood juices are not associated with poultry meat as they are with red meat.

Various methods of stunning and slaughtering have been shown to effect carcass quality, rigor development and meat quality. In particular, it was held that using high voltages in a waterbath stunner played a part in producing poor bleeding, haemorrhages and broken bones.

Observations of the blood loss rate after low and high voltage are conflicting. Kotula and Helbacka (1966a) reported that electrical stunning resulted in significantly more retained blood in the saleable parts as opposed to either physically stunning or non-stunned birds. Kotula and Helbacka (1966b) also reported that electrical stunning did not significantly affect total blood loss as a percentage of live bird weight, but as a percentage of total blood volume, was significantly less than physically stunned birds. Kuenzel and Inglis (1977) attempted to evaluate two types of stunning (a plate stunning and a brine stunning) and two types of circuits (AC and DC currents) in order to determine which was best for maximizing bleed-out in broilers. The authors found that an AC circuit connected to a brine stunner at a voltage setting of 50 V was best for maximizing bleed-out of electrically stunned male broilers.

Researchers have shown that electrical stunning not only reduces pain (Kuenzel and Walther, 1978), but aids in the bleed-out of poultry (Kuenzel et al., 1978). On the other hand, Veerkamp and de Vries (1983) reported that increasing stunning voltages of 75, 100, 135, 165, and 200 V resulted in decreased blood loss when measured at 90, 160, 240, or 300 seconds post-mortem. Griffiths (1983) found no differences between the amount of blood draining from broilers stunned at 50, 80, 105 or 200 V — nor was there any detectable difference in the appearance of carcasses. Griffith et al. (1985) also compared stunning voltages from 55 to 240 V and concluded that stunning and/or electrocution had no effect on blood loss during killing or carcass appearance after processing. Dickens and Lyon (1993) reported that stunning with either 50 or 200 V AC had no effect on blood loss of broilers. Fletcher (1993) reported that the effects of electrical stunning on broilers' blood loss are not an absolute effect.

Carcass and meat defects associated with electrical stunning are skin discoloration, red wingtips, broken bones, and muscle haemorrhaging. Veerkamp and de Vries (1983) compared the effect of 75 and 200 V electrical Stunning on carcass color. The authors found that stunning at 200 V resulted in significantly more red wingtips and tails than broilers stunned at 75 V.

An increase in blood pressure during stunning can cause blood vessel damage. Lyon and Lyon (1986) found that 80 to 90% of the cases were suspect surface spots due to blood vessel damage. Gregory and WIlkins (1989a) reported that failure to bleed the chickens which had a ventricular fibrillation (VF) at stunning process resulted in high incidences of red wingtips, haemorrhaging at the humerus-radius joint, and red sternal feather tracts when compared to non-fibrillated stunning. The authors concluded that fibrillation resulted in slightly slower initial bleeding.

The breast muscle pH values in broilers drop very rapidly upon death, specially when it is either deboned or served within 15 to 30 minutes of slaughter. Kijowski et al. (1982) reported that the onset of rigor in broiler breast meat commenced within 30 to 60 minutes post-mortem as measured by adenosine triphosphate level, lactic acid concent, pH value, sarcomere length, and water and fat retention capacity. The pH decline between 2 and 24 hours post-mortem was not significant and ranged from 5.8 to 5.73. Lyon et al. (1984) reported that pH of broiler breast muscle did not decline significantly between 1.5 and 24 hours post-mortem and averaged 5.7 for this time. Stewart et al. (1984) reported that breast muscle pH values can drop between 65 to 80% of their capability (from a normal resting muscle pH of 7.25 to final post-rigor pH of 5.75) within the first 30 to

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60 minutes after death. THOMSON et al. (1986) reported that electrical stunning resulted in higher muscle pH values 20 minutes post-mortem, but there were no differences after 24 hours. KIM et al. (1988) also observed a higher muscle pH in a stunned broiler chicken 20 minutes to 1 hour after post-mortem.

MOHAN RAJ et al. (1990) reported that electrical stunning resulted in higher muscle pH values at 20 minutes post-mortem as compared to CO₂ or argon gas stunning (6.56, 6.37 and 5.91 respectively). After 24 hours, although significantly different, the differences were much smaller with values ranging from 5.77 (CO₂, argon stunning) to 5.83 (electrical stunning). Fletcher (1993) reported that various methods of stunning and killing have been shown to affect carcass quality, rigor development and meat quality. Electrical stunning has been shown to result in a slower rigor development, higher muscle pH, and more tender meat. The author concluded that electrical stunning temporarily retards carcass quality, rigor development and meat quality.

**Materials and Methods**

The same strain, age, and weight of broiler chickens were used in the experiments (Ross 208, 41-day-old, about 2 kg). Feed was withdrawn from broilers 8 to 12 hours prior to slaughter. All birds were stunned in a water-bath stunner and processed in a commercial slaughterhouse. The processing in this slaughterhouse is briefly described as follows:

- **Capacity:** 5100 broilers/hour
- **Time between hanging and stunning = 35 seconds**
- **Stunning:** In a water-bath stunner (Linco, Lindholdst stunner), AC circuit (voltage) = 10 seconds
- **Time between stunning and slaughtering = 12 seconds.**
- **Bleeding:** Manual slaughtering by severing the jugular veins and carotid arteries on both sides of the neck = 135 seconds
- **Scalding:** In a thermostatically controlled scalding tank (Linco, Lindholdst scaldor) equipped with a circulating pump discharging the water at the top of the tank and over the immersed birds = 100 seconds
- **Plucking:** Mechanical plucking (Linco, Lindholdst plucker) = 40 seconds
- **Evisceration:** With an automatic viscera removal apparatus (Stork, the Netherlands)
- **Chilling:** In a counter-current chiller (Linco, Lindholdst chiller) = 35 minutes.

**Experiment 1:** Two-hundred broiler chickens were used in this experiment. Five treatment groups were set up with forty broilers each. Birds were individually stunned at 0, 23, 53, 103, and 193 V for 10 seconds, manually slaughtered, and allowed to bleed for 135 seconds.

To calculate the blood loss of the broilers, the following measurements were executed: The weight was measured alive before stunning and the weight was measured 147 seconds after stunning (with venetion 12 seconds after stunning). The water uptake of the broilers was measured with other birds at the same time from the same flock. For this purpose the weight was measured both before stunning and 147 seconds after stunning. The blood loss of individual broilers was calculated from the measured values, using the following formula:

\[ Y = X - X_t + W_t, \]

where \( Y \) = weight of blood loss t seconds after stunning, \( X \) = live weight, \( X_t \) = weight t seconds after stunning, \( W_t \) = amount water uptake t seconds after stunning.

The total blood volume of the individual broilers was calculated using the formula of Kotula and Helbacka (1966b):

\[ Y = 2.251 \times X^2 - 11.1 \times X + 20.49, \]

in which \( Y \) = total amount of blood as percentage of live weight, \( X \) = live weight in kg.

The blood loss was expressed as a percentage of the total blood volume to exclude influences of the differences in average weight between the different samples.

**Experiment 2:** 7,280 broiler chickens were slaughtered on the same day. The birds were subjected to 0, 50, 100, and 200 V AC stun for 10 seconds in groups 1, 2, 3, and 4 respectively, killed approximately 12 seconds after stunning and were allowed to bleed for 135 seconds. Immediately after bleeding the birds were scalded for 100 seconds at 60 °C. Mechanically plucked, eviscerated, and then chilled for about 35 minutes. No carcasses with visible defects were used in the study.

To quantify the problem of red wingtips, red feather tracts, haemorrhagic wing veins, and shoulder haemorrhage, the study adopted a visual grading system in which the carcasses were individually examined and inspected in order to determine and evaluate the above mentioned damage.

**Experiment 3:** The same procedure as in experiment 2. 3,960 broiler chickens were used and slaughtered on the same day. The birds were stunned at 0, 50, 100, and 200 V for 10 seconds in groups 1, 2, 3, and 4, respectively. To evaluate the effect of different stunning voltages on the incidences of broken bones, the carcasses used in the study were individually examined for the above mentioned damage.

**Experiment 4:** The same procedure as in experiment 2. 75 broiler chickens were used in this experiment. The birds were stunned for 10 seconds at 0, 33, 53, 103, and 200 V AC in groups 1, 2, 3, 4, and 5, respectively. To examine the effect of different stunning voltages on breast haemorrhages (blood spots), a visual grading system was followed in which the pectoralis major muscles were individually examined and evaluated by a trained panel for the above mentioned damage.

**Experiment 5:** Twenty broiler chickens were used in this experiment. Each bird was allocated to one of two treatments, which differed in the voltages used to stun the birds; the voltages used were 50 and 200 V AC for 10 seconds. No birds with visible defects were used in the experiment.

The pH values were recorded at 20 minutes, 2 and 24 hours post-mortem with a digital pH meter (Kinck - Portamesse 751, calimatic, W. Germany) equipped with an Ingold glass electrode (model, 453 — S7); the electrode was inserted 3 cm into the anterior end of the pectoralis major muscle.
Table 1. The blood loss in relation to voltage setting and time after slaughtering as a percentage of live weight and total blood volume

<table>
<thead>
<tr>
<th>Stun V AC</th>
<th>n</th>
<th>LW (g)</th>
<th>BL (g)</th>
<th>TBV (%)</th>
<th>BL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>40</td>
<td>2099 ± 95</td>
<td>63.75 ± 17b</td>
<td>7.12 ± 0.15</td>
<td>42.25 ± 11b</td>
</tr>
<tr>
<td>23</td>
<td>38</td>
<td>2206 ± 83</td>
<td>59.35 ± 12a</td>
<td>6.97 ± 0.09</td>
<td>38.54 ± 8a</td>
</tr>
<tr>
<td>53</td>
<td>40</td>
<td>2185 ± 113</td>
<td>82.41 ± 12d</td>
<td>7.01 ± 0.17</td>
<td>53.74 ± 6d</td>
</tr>
<tr>
<td>103</td>
<td>42</td>
<td>2134 ± 146</td>
<td>80.39 ± 15d</td>
<td>7.09 ± 0.22</td>
<td>53.04 ± 11d</td>
</tr>
<tr>
<td>193</td>
<td>22</td>
<td>2071 ± 96</td>
<td>75.75 ± 14c</td>
<td>7.17 ± 0.18</td>
<td>51.04 ± 9c</td>
</tr>
</tbody>
</table>

- Means ± Standard Error (S.E.)
- Means within a column with no common superscripts differ significantly (P < .05).
- LW = live weight; BL = blood loss; TBV = total blood volume.

Table 2. Effect of different stunning voltages on the percentage of carcass defects in broiler chickens

<table>
<thead>
<tr>
<th>Stunning treatment (Volt)</th>
<th>n</th>
<th>Birds with the noted defect, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>450</td>
<td>Birds with one or more broken bones</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>Birds with broken scapula</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td>Birds with broken wings</td>
</tr>
<tr>
<td>200</td>
<td></td>
<td>Birds with broken clavicle</td>
</tr>
<tr>
<td>Red wingtips</td>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td>Red feather tracts</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Haemorrhagic wing veins</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Shoulder haemorrhage</td>
<td>9</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 3. Effect of different stunning voltages on the percentage of broken bones in broilers

<table>
<thead>
<tr>
<th>Stunning treatment (Volt)</th>
<th>n</th>
<th>Birds with the noted defect, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>450</td>
<td>Birds with one or more broken bones</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>Birds with broken scapula</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td>Birds with broken wings</td>
</tr>
<tr>
<td>200</td>
<td></td>
<td>Birds with broken clavicle</td>
</tr>
<tr>
<td>Birds with one or more</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>broken bones</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>Birds with broken scapula</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Birds with broken wings</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>Birds with broken clavicle</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Birds with broken coracoid</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The pH meter was calibrated with two special buffers (7.00 and 4.01 pH) and adjusted to the temperature of the samples at the time of recording the pH values.

Statistical Analysis: Results were subjected to analysis of variance, General Linear Models Procedure and Least Square Means using the Statistical Analysis System (SAS, 1989). Significance (p < .05) was determined using the F test.

Results

Experiment 1: Results are summarized in table 1 indicating that blood loss was inversely related to stunning voltage. There was significant variation among individuals in the amount of bleeding-out irrespective of the method of slaughtering. No or low stunning voltage (0 to 23 V) caused the chickens to leave the stunner speaking loudly and flapping their wings in vain efforts to flee and resulted in significantly (P < .001) poor bleeding (38 to 42%) compared to the amount of blood loss from broilers stunned at higher voltages (53, 103, and 193 V). Stunning voltages of 53, 103, and 193 V resulted in no significant differences (P > .05) in blood loss when measured at 135 seconds post-mortem. These results were in close agreement of those found by Griffiths (1983) and Griffiths et al. (1985) who found no differences between the amount of blood draining from broilers stunned at 50, 80, 105, and 200 V.

The results in Table 1 show that a 193 V-stun, which is sufficient to cause cardiac arrest, had no adverse effect on blood loss. This result supports the earlier work of Warriss (1984) who also found that a beating heart is not necessary to ensure effective bleed-out.

Experiment 2: The results are presented in table 2 and indicate that electrical stunning voltages significantly affect the rate of red wingtips, red feather tracts, haemorrhagic wing veins, and shoulder haemorrhage in the carcass of the slaughtered broilers. The incidences of carcass defects were increased with the increasing of the applied electrical voltages for stunning. Stunning at 200 V resulted in significantly greater incidences of red wingtips and red feather tracts than other applied stunning voltages (50 and 100 V). These results were in agreement with those of Gregory (1989a) who reported that failure to bleed the chickens which had ventricular fibrillation (VF) resulted in higher incidences of red wingtips. The highest incidences of haemorrhages in wing veins and shoulder occurred at 100 V stun.

Experiment 3: The results are summarized in table 3 and indicate that variation of stunning voltages from 0 to 200 V significantly affects the frequency of broken bones in slaughtered broilers. The frequency of broken bones increased with the increasing of stunning voltage. Stunning at 0 and 200 V results in significantly higher incidences of broken bones than 50 and 100 V. Number of carcasses with broken wings or legs was decreased with the increase of the stunning voltages. No broken scapula or coracoid were observed in all treatments of the experiment.

Experiment 4: The results are presented in table 4 and indicate that severity of breast haemorrhage increased with increasing stunning voltage. The highest incidences of breast haemorrhages were observed at 200 V.
Carcasses stunned at 33 and 53 V were graded as A quality, while the carcasses stunned at 103 and 200 V AC were graded as B and C, respectively. This result indicates that the applied electrical voltage for stunning has a direct effect on the quality grades of the carcasses.

Experiment 5: The results are summarized in Table 5. Muscle pH values at 20 minutes, 2 and 24 hours post-mortem were 6.48, 6.39 and 5.86, respectively, for 50 V stunned birds and 6.24, 6.02, and 6.01, respectively, for 200 V stunned birds. Muscle pH values were significantly higher for 50 V stunned birds. The most pronounced effect of electrical stunning on pH was in the differences for readings taken within 20 minutes and 2 hours post-mortem. The 20 minutes and 2 hours post-mortem pH for breast meat from the group stunned at 50 V AC was significantly greater (P < .05) than meat from the group stunned at 200 V AC (Table 3). The post-mortem pH decline appears to plateau after 24 hours; there was no significant difference between the 24 hours pH values from birds stunned at 50 and 200 V. These results were in agreement with the findings of Scott, (1978); Thomson et al., (1986); Mohan Raj et al., (1990) and Fletcher, (1993).

In Table 5 the greatest pH drop for the group stunned at 50 V AC (high post-slaughter pH) occurred between 2 and 24 hours post-mortem and for the group stunned at 200 V AC (low post-slaughter pH), was between 20 minutes and 2 hours post-mortem. This result supports the earlier study of Khan (1974) and confirms that muscle with low post-slaughter pH values went into rigor sooner (after death) than muscle with high post-slaughter pH values.

Discussion and Conclusion

The results in tables 1, 2, and 3 show that stunning at 50 V for 10 seconds seems to be more effective in bleed-out and results in better carcass quality compared to other applied voltages. These results are in close agreement with those of Kuenzel and Ingling, (1977), who found that 50 V AC was superior for maximizing bleed-out in processed chickens. Griffiths (1983) and Griffiths et al. (1985) who observed no difference between the amount of blood lost from broilers stunned at 55, 80, 105, or 200 V, and Dickens and Lyon (1993) who reported that stunning with either 50 or 200 V AC had no effect on blood loss of broilers. These results indicate that the use of higher voltages for stunning (above 103 V) could be used without any detrimental effect on blood loss as long as the standard bleeding time of 135 seconds was maintained.

The results of this study disagree with those of Heath, (1984); Gregory and Wotton, (1986); Mews, (1993); Gylbergs, (1993) and Lambooij, (1993), who recommended high electrical stunning which causes heart failure/immediate death as a suitable solution to the problem of animal welfare and humane treatment of food animals during slaughter. The disagreement is based on the indications, which have shown that high electrical stunning voltage adversely affects meat quality and carcass appearance, lengthens the bleeding time, increases the risk of broken bones and contamination on the birds and causes difficulties in plucking due to onset of rigor mortis after an excessively long bleeding time. Also, the religious and cultural considerations for Kosher and Halal slaughter requirements as well as other marketing systems require different restraints and regulations for stunning.

Table 4. Effect of different electrical stunning voltages on breast blood spots in broiler chickens

<table>
<thead>
<tr>
<th>Treatment (V)</th>
<th>Carcasses with blood spot, %</th>
<th>Eval. of blood spot numbers per breast</th>
<th>Quality grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>15</td>
<td>40</td>
<td>S</td>
</tr>
<tr>
<td>50</td>
<td>15</td>
<td>33</td>
<td>NS</td>
</tr>
<tr>
<td>103</td>
<td>15</td>
<td>35</td>
<td>NS</td>
</tr>
<tr>
<td>200</td>
<td>15</td>
<td>86</td>
<td>S</td>
</tr>
</tbody>
</table>

For example, in some countries birds are simply not stunned, due to religious or market demands. This study suggests that alternative stunning methods combined with a low electrical stunning should be investigated in order to eliminate the conflict conditions conducive to animal welfare and to product quality. However, from both a welfare and a commercial point of view, it is essential that both carotid arteries and jugular veins are cut as soon as the blood vessels. Blackmore and Delany (1988) commented that in order to ensure that a slaughter process is humane, it is important to know the time taken for an animal to become insensible from sticking procedure alone.

Data in Table 5 clearly show that different stunning voltages resulted in significantly different muscle pH values up to 2 hours post-mortem. After 24 hours, there was no significant difference between the 24-hours pH values from the birds stunned at 50 and 200 V AC. These results agree with the findings of Scott, (1978); Thomson et al., (1986); Mohan Raj et al., (1990) and Fletcher, (1993).

The ability of electrical stunning to elevate the pH at the early post-mortem period could be very important to the functional properties of the breast meat. Froning and Neelakantan (1971) reported that the pH of 5.9 or higher could be used to indicate a pre-rigor condition in broiler breast meat; meat with a pH of 5.9 was correlated with increased functional properties when compared with post-rigor meat with a lower pH. Kijowski et al. (1982) reported that the onset of rigor in the broiler breast meat commenced within 30 to 60 minutes post-mortem as measured by adenosine triphosphate level, lactic acid content, pH value, sarc came length, and water and fat capacity.

In conclusion, different stunning voltage significantly affects blood loss, carcass quality and appearance, and early...
post-mortem pH. Stunng at 50 V AC for 10 seconds could be used without any detectable adverse effects on the above mentioned characteristics.

Summary

Five experiments were conducted to examine the effect of different stunning voltages on blood loss, carcass quality and breast muscle pH. Broilers were stunned in a water-bath stunner for 10 seconds at selected electrical voltages.

In the first experiment, the total blood volume (TBV) of the individual broilers was calculated using the formula of KOTULA and HELBACKA (1966b). In the second, third and fourth experiments, to determine the quality problem of the carcasses, the study adopted a visual grading system in which the carcasses were individually examined by a selected trained panel. In the fifth experiment, the pH values were recorded with a digital pH meter (KNICK-portamess 751, calmatic, W. Germany) equipped with an Ingold glass electrode (model 453 — S7). The percentage of blood loss, was significantly affected by the different stunning treatment, which averaged 42.3, 38.5, 53.7, 53, and 51% for 0, 23, 53, 103, and 193 V AC, respectively. This study indicated that stunning voltages higher than 100 V could be used without any detrimental effect on blood loss as long as the standard bleeding time of 135 seconds is maintained. Adverse effects were observed on the carcass quality and appearance from birds stunned at 103 and 193 V AC. Stunng at 50 V AC resulted in a significantly higher pH up to 4 hours post-mortem. After 24 hours post-mortem, no differences were observed in pH values from birds stunned at 50 or/and 200 V AC.

It was concluded that stunning at 50 V AC for 10 seconds could be used without any detectable adverse effects on blood loss, carcass quality and breast muscle pH.

(Key words: broiler, different stunning voltages, meat quality, blood loss, muscle pH)

Effekt verschiedener Voltzahlen bei der Betäubung auf Blutverlust, Schlachtkörperformqualität und pH des Brustmuskels.

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Zusammenfassung


Im ersten Versuch wurde den totalen Blutgehalt der einzelnen Broiler nach der Formel von KOTULA & HELBACKA (1966b) berechnet. Im zweiten, dritten und vierten Versuch wurde ein visuelles Beurteilungssystem benutzt, indem die Körper von ausgewählten, geübten Testern individuell beurteilt wurden, um die Qualität der Schlachtkörperform zu bestimmen. Im fünften Versuch wurden die pH-Werte mit einem digitalen pH-Meter (Knick-portamess 751, calmatic, Deutschland) mit einer Ingold Glaselektrode (Modell 453 — S7) registriert.


Die Konklusion ist, daß Betäubung bei 50 V Wechselstrom für 10 Sekunden ohne spürbare, abträgliche Wirkungen auf Blutverlust, Qualität des Körpers und pH des Brustmuskels verwendet werden kann.

Stichworte:
Broiler, Schlachtung, Betäubung, Stromspannung, Blutverlust, Schlachtkörperformqualität, pH

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References


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