

1 **The effect of the required current/frequency combinations (EC 1099/2009) on the**
2 **incidence of cardiac arrest in broilers stunned and slaughtered for the halal market.**

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11 **Abbreviated Title:** Water bath stunning on ECG

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13 **Summary**

14 Multi-bird water bath stunning is the only method permitted for stunning broilers in halal
15 plants in the UK. The electrocardiogram (ECG) was measured in broilers that were stunned
16 electrically in a commercial water bath using four of the frequency/current parameters
17 permitted under EU Regulation (1099/2009) plus a control treatment (pulsed DC waveform).
18 The results showed that there were no differences between the treatments in that all the birds
19 displayed a rhythmic heart beat following stunning and before slaughter.

20 An opportunity to observe recovery in a small number of broilers (nine) in a Spanish
21 processing plant suggested that AC at 1000 Hz applied at 200 mA per bird would also meet
22 both the legislative requirements and the needs of the halal market, in that all birds recovered
23 from the stun.

24

25 **Keywords:** *poultry, halal slaughter, water bath stunning, EU Regulation, frequency,*
26 *current*

27

28 **Introduction**

29 With an increasing population of Muslims in the UK, 2.4 million in 2009 (Kerbaj, 2009), the
30 halal food market has received progressively more attention. The Muslim population have

31 strict dietary requirements, based on the Qur'an (Riaz & Chaudry, 2003) and met through
32 specific halal markets. In terms of meat consumption, Muslims are prohibited from eating
33 pork, so beef and poultry are the preferred animal products (Havinga, 2010). In addition,
34 Muslims are also prohibited from eating the meat from animals that are not alive at slaughter.
35 Therefore, they either slaughter animals without stunning or slaughter animals with stunning,
36 using a stunning method that does not result in the death of the animal. For birds, the only
37 stunning method that is accepted by Muslims in the UK is electrical water bath stunning
38 (Nakyinsige et al., 2013).

39 Previous research with chickens (Gregory and Wotton, 1987) has shown that cardiac muscle
40 is particularly sensitive to electrical stimulation, but only at low frequencies i.e. 50 Hz. The
41 magnitude of the applied current can also contribute to the incidence of cardiac arrest (known
42 as stun to kill, when deliberate) and that the minimum required alternating current (AC) of
43 100 mA per bird at a low frequency such as 50 Hz will result in the death of about 80 - 90%
44 birds (Gregory and Wotton, 1988, 1990). Wilkins, et al., (1998) showed that the use of
45 frequencies progressively greater than 50 Hz was associated with a failure to induce a cardiac
46 arrest. Therefore, where birds are processed for the Halal market, the use of high frequency
47 AC will ensure that stunned birds are not killed in the water bath stunner but are alive when
48 their necks are cut.

49 Consequently, those with a concern for animal welfare want to encourage methods that will
50 enable the production of halal poultry meat from birds that are stunned prior to slaughter.
51 However, there is a compromise because water bath stunning per se has the potential to create
52 welfare issues (Wotton and Wilkins, 2004), specifically variations in bird resistance will
53 result in variations in the current received by individual birds. In addition, further research
54 into the electrical parameters required for effective water bath stunning has raised anomalies.
55 This is because processing plants that produce halal meat have preferred historically to use a
56 very low current combined with high frequency pulsed DC to stun the birds, which they
57 believe will guarantee that the birds will not incur ventricular fibrillation during stunning
58 (Gregory et al., 1991). Raj, et al. (2006a,b,c) looked at whether increased frequencies
59 combined with different waveforms would result in effective stunning. Their research showed
60 that the minimum current to effectively stun increased with increasing frequency for AC and
61 that pulsed DC was not effective unless applied at very much higher current levels. They
62 suggested that at lower current levels, when applied as pulsed DC, birds could be electrically
63 immobilized and not stunned. The minimum currents proposed by Raj, et al. (2006a,b,c,) that

64 would produce effective water bath stunning were confirmed by Prinz (2009) and
65 incorporated into EC Regulation (1099/2009) as reproduced in table 1.

66 **Table 1.** AC electrical requirements for water bath stunning equipment
67 (average values per animal)

Frequency (Hz)	Chickens	Turkeys	Ducks and geese	Quails
< 200 Hz	100 mA	250 mA	130 mA	45 mA
From 200 to 400 Hz	150 mA	400 mA	Not permitted	Not permitted
From 400 to 1500 Hz	200 mA	400 mA	Not permitted	Not permitted

68
69 The new EC Regulation (1099/2009) does offer processors a choice from three ranges of
70 current and frequency combinations to stun chickens before slaughter. However, there is
71 some concern voiced from the Muslim Authorities that these parameters may result in the
72 death of a proportion of birds prior to slaughter. Indeed, there is little published information
73 on whether these parameters would induce ventricular fibrillation and hence result in the
74 death of the bird in the water bath stunner. The research described below was designed to
75 make an important contribution to the field of pre-slaughter stunning of birds for the halal
76 market by quantifying the effect of these new parameters in terms of the incidence of induced
77 ventricular fibrillation.

78

79 **Materials and methods**

80 The trial was conducted over a total of three days in a commercial halal plant with the
81 approval of the University of Bristol Ethical Review Group (UIN/13/037). The broilers were
82 supplied from five different farms. A total of 759 broilers were studied, randomly selected
83 from 17 separate transport loads. The experimental design ensured that birds were evenly
84 distributed across the treatment groups (Table 2) such that treatments 1 to 3 and treatments 4
85 & 5 each contained a similar number of broilers from each load.

86 The birds were weighed on arrival at the processing plant before loading onto the primary
87 processing line. The average bird live weight was 1.83 kg for treatments 1 to 3 and was

88 similar for the different loads used. The birds used for treatments 4 & 5 had an average live
89 weight of 1.90 kg.

90

91 Table 2. The five treatment groups that were tested for their effect on bird heart function.

No.	No. of birds	RMS Current (mA/bird)	Frequency (Hz)	Waveform	Origin
1	152	45	500	Pulsed DC	'Control' waveform - favoured for halal
2	152	102	200	Sinusoidal AC	EC Regulation (1099/2009)
3	152	146	400	Sinusoidal AC	
4	151	199	600	Square wave AC	
5	152	199	1500	Square wave AC	

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94 The electrical parameters used for all five treatments were applied for 5.7 s (dwell time) in a
95 commercial water bath stunner regulated using a factory calibrated Poultry Stun Monitor
96 (AGL Consultancy Ltd.) in conjunction with a factory calibrated "Fluke" Scopemeter (Fluke
97 UK Ltd.). Following stunning and slaughter, individual birds were removed from the
98 processing line and placed on a single shackle mounted on an A-frame to enable ECG
99 recordings to be made. Fine needle electrodes were inserted intrathoracically in each bird >15
100 s after both carotid arteries were severed manually and the signal was amplified using a pre-
101 amp (Gould Bioelectric, UK). The signal was subsequently passed through a noise removal
102 system (Humbug 50/60 noise removal system) to eliminate the background noise and
103 digitally recorded at a sampling rate of 1,000 samples per second using a Vision Data
104 Acquisition System (LDS Test & Measurement Ltd.). Each trace was analysed in real time
105 for the presence of a repeating QRS complex (Figure 1).

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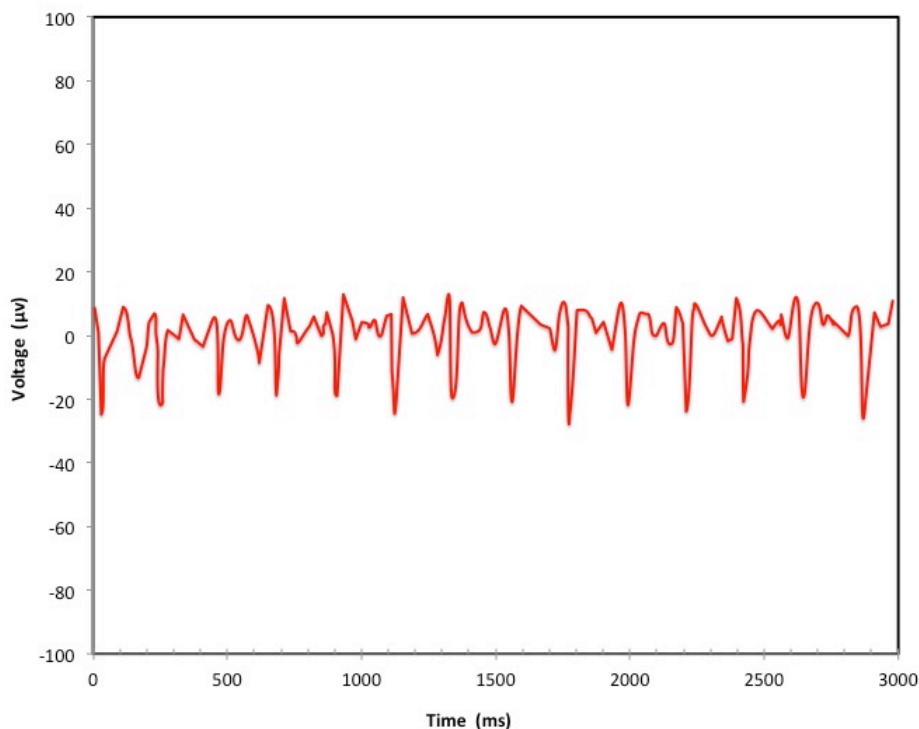
107 The results were statistically analysed and are presented as the percentage of birds that did
108 not recover together with a 95 per cent confidence interval for the percentage calculated using
109 Wilson's method (Altman et al, 2000).

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Figure 1. Post stun ECG of a broiler that was stunned using a 100 mA at 200 Hz, AC waveform.

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117 Results

118 All of the 759 broilers studied demonstrated a repeatable cardiac rhythm following the
119 application of the electrical water bath stunning treatment. None of the birds suffered a
120 ventricular fibrillation, which would lead to a cardiac arrest. Wilson's method gives a 95%
121 confidence interval for this proportion (zero) within a single treatment as ranging from 0 to
122 2.5 per cent. Thus given the sample size of 152 it is unlikely that the true underlying
123 proportion that would have had a cardiac arrest would be greater than 2.5%. Given that all
124 the treatments resulted in zero per cent cardiac arrest it is possible to calculate a confidence
125 interval across the treatments used as a whole. However, we omit treatment 1 from this
126 calculation as it is now outside the law (EC Regulation 1099/2009). Thus, Wilson's method
127 gives a 95 per cent confidence interval of 0 to 0.6 per cent for the 0 per cent cardiac arrest
128 from the 607 birds within treatments 2 to 5. Hence, it is unlikely that an underlying figure for

129 birds showing cardiac arrest would ever be greater than 0.6%. Figure 1 show a typical ECG
130 recording of a broiler that was stunned by approximately 100 mA at 200 Hz, 131 Volts
131 alternating current (VAC) given an average dwell time of 5.7 s in a water bath that immersed
132 10 birds in the water bath at any one time. The ECG recordings demonstrate that the birds
133 did not develop a cardiac arrest through ventricular fibrillation as a result of the stunning
134 treatments applied.

135 The mean stunning current for treatments 1, 2, 3, 4 and 5 was approximately 45 mA, 102 mA
136 and 146 mA, 199 mA and 199 mA, respectively (Table 2). In order to achieve the required
137 current per bird, the voltage was manually adjusted. When selecting the mid-range
138 current/frequency combination (treatment 3) to stun birds, the range of the voltage required to
139 maintain 146 mA was 168 V to 200 V across the different birds from the different transport
140 loads. The stunning dwell time within the water bath stunner varied slightly between
141 treatments and loads.

142 During the experiment, the birds sampled were from 17 separate transport loads and these
143 loads came from different farms. Although the number of birds sampled from each load, for
144 each treatment was not identical, this should not have affected the results obtained.

145

146 **Discussion**

147 Muslims cannot eat the meat from animals that are not alive at the point of slaughter.
148 Historically this requirement has been achieved by applying low current, pulsed DC at high
149 frequency and by rejection of any birds that were deemed to be already dead at neck cutting
150 by the halal slaughterman. Research has shown that pulsed DC and AC waveforms when
151 applied at low current levels may not produce consistent stunning (Raj, et al., 2006a,b,c;
152 Prinz, et al., 2010). The use of low average currents represents a welfare concern,
153 particularly for the female broilers, which have a higher resistance (Rawles, et al., 1995;
154 Prinz, 2009) and therefore would receive a substantially lower current than the calculated
155 average current per bird. Water bath stunning systems are at present constant voltage by
156 design; a constant voltage is applied between a 'live' water bath electrode and an earthed rail
157 that makes contact with the shackles. On average more than 10 birds are immersed in the
158 water bath and subjected to the stunning voltage at any one time. The major concern over the
159 calibration of water bath stunners for poultry is the potential large variation in impedance (i.e.

160 resistance to the flow of electrical current) between birds within the stunner. Major variation
161 in bird impedance can be caused by the interface between the bird's leg and the shackle.
162 Variations in the size of the legs of birds and the development of the leg-scales can produce
163 large variations in contact impedance (Wotton and Wilkins, 2004)

164 Higher stunning frequencies in the past have been shown to produce a lower incidence of
165 broken bones and breast muscle haemorrhages (Raj et al., 2001), which are likely to be the
166 drivers behind the frequencies chosen commercially. The use of higher frequencies also
167 reduces the likelihood of birds suffering from a cardiac arrest.

168 The requirement of EC Regulation (1099/2009) is for the application of a range of
169 current/frequency combinations, where the magnitude of the minimum currents (table 1) are
170 significantly higher than those employed in the past. Concern has been expressed by some
171 Halal Certification Bodies that these higher currents will result in the death of birds in the
172 water bath. However, there can be no derogation for the use of those parameters applied
173 previously for halal production as that would result in the Competent Authority approving
174 current and frequency combinations that were insufficient to stun (Raj, et al., 2006a,b,c;
175 Prinz, et al., 2010).

176

177 EC Regulation (1099/2009) requires the use of electrical parameters that specify minimum
178 currents within a defined frequency range. These legislative requirements should be applied
179 in all processing plants that employ electrical water bath stunning, including those plants
180 supplying the Muslim community. However, it has been reported that some Halal
181 Certification Bodies are concerned about these parameters as some of the current/frequency
182 options have the potential to result in the death of birds during the stunning process. The
183 results from this study should allay the concerns of the Certification Bodies and permit the
184 continued use of electrical water bath stunning for the production of halal poultry products,
185 but at current and frequency combinations that encourage the effective stunning of birds prior
186 to slaughter.

187

188 **Conclusion**

189 On welfare grounds this work describes how the use of specific parameters permitted by the
190 newly required electrical combinations to stun birds produces an effective stun (EC
191 Regulation 1099/2009) and is not contradictory to the requirements of many Halal
192 Certification Bodies.

193 In summary, the four recommended combinations of current and frequency studied during
194 this project did not induce a single cardiac arrest at stunning. Following stunning, it is also
195 important to ensure that the requirement for both carotid arteries to be severed at slaughter
196 (EC 1099/2009) is met because the birds stunned with the current/frequency combinations
197 tested will have the possibility of regaining consciousness.

198 Subsequently to this study, an opportunity occurred at a Spanish poultry processing plant
199 (Avicola Sanchez S.A) to assess the effect of two frequency/current combinations on a
200 limited number of broilers. The study was approved beforehand by the Institutional Animal
201 Care and Use Committee (IACUC) of the Catalan Government. The trial occurred towards
202 the end of the normal processing shift on twelve broilers ranging between 2.0 & 2.8 kg live
203 weight. The birds were stunned in the plant's commercial water bath stunner that was
204 adjusted to deliver either 600 Hz (n = 3) or 1000 Hz (n = 9), square wave AC at 200 mA per
205 bird. Following stunning, birds were randomly removed from the processing line before neck
206 cutting, placed in a meat crate for observation and allowed to recover. The water bath
207 parameters were calibrated and recorded on a Vision Data Acquisition System (LDS Test &
208 Measurement Ltd.). Current measurement was made using a PR 30 (LEM HEME Ltd.)
209 current probe and voltage measurement using direct leads between the live water and earthed
210 rail.

211 The application of 200 mA at 600 Hz resulted in the death of two of three birds initially
212 tested. When the frequency was increased to 1000 Hz (200 mA per bird) all of the further
213 nine birds tested recovered consciousness within 1 minute of the water bath stunner exit.

214 It is concluded that in order to meet both the legislative requirements (EC Regulation
215 1099/2009) for pre-slaughter stunning and the halal requirements for a live bird at slaughter,
216 a minimum AC frequency of 1000 Hz at 200 mA per bird would be a reasonable
217 compromise.

218 **Acknowledgements**

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220

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