



Fuseini, A., Teye, M., Wotton, S., Lines, J., & Knowles, T. (2018). Electrical water bath stunning for Halal poultry meat production: Animal welfare issues and compatibility with the Halal rules. *CAB Reviews*, 13(16), 1-7. <https://doi.org/10.1079/PAVSNNR201813016>

Peer reviewed version

Link to published version (if available):
[10.1079/PAVSNNR201813016](https://doi.org/10.1079/PAVSNNR201813016)

[Link to publication record in Explore Bristol Research](#)
PDF-document

This is the author accepted manuscript (AAM). The final published version (version of record) is available online via CABI at <https://www.cabi.org/cabreviews/review/20183202812>. Please refer to any applicable terms of use of the publisher.

University of Bristol - Explore Bristol Research

General rights

This document is made available in accordance with publisher policies. Please cite only the published version using the reference above. Full terms of use are available: <http://www.bristol.ac.uk/red/research-policy/pure/user-guides/ebr-terms/>

Electrical water bath stunning for Halal poultry meat production: Animal welfare issues and compatibility with the Halal rules.

Awal Fuseini^a, Moses Teye^b, Steve B. Wotton^a, Jeff A. Lines^c, Toby G. Knowles^a

^aSchool of Veterinary Sciences, University of Bristol, Langford, Bristol, BS40 5DU

^bDepartment of Animal Science, School of Agriculture, College of Agriculture and Natural Sciences, University of Cape Coast, Ghana.

^cSilsoe Livestock Systems Ltd, Wrest Park, Silsoe, Bedfordshire MK45 4HR, UK

Abstract

The use of electrical water bath stunning for the ‘humane’ slaughter of poultry has drawn criticism from some animal welfare research scientists and animal welfare organisations throughout the world. During water bath stunning, birds are shackled and inverted prior to entry into an electrified water bath, current is passed from the head, through the body and legs to earth via stainless steel shackles. From a Halal perspective, the rules stipulate that the welfare of animals are protected at all times, and that animals must be alive (not conscious) at the point of neck-cutting. Some Muslim authorities have therefore questioned the suitability of water bath stunning for Halal meat production due to its negative impact on animal welfare and the possibility of some birds dying prior to exsanguination. This paper examines possible welfare compromises during water bath stunning and how these may affect compatibility with the rules of Halal meat production.

Keywords: Water bath stunning; Animal Welfare; Halal; Slaughter;

1. Introduction

Some aspects of the transportation, pre-slaughter handling, stunning and neck-cutting of poultry have been shown to negatively impact the welfare of birds. Figure 1 below is a flow chart of primary processing operations leading to the bleeding-out of poultry following water

bath stunning. Due to the design of transport modules and the way poultry are transported from farms to abattoirs, it is virtually impossible to monitor the welfare of every bird in transit or, on arrival. During ante-mortem inspections at the abattoir, ideally, the welfare of every bird and its fitness for slaughter should be assessed, however in practice, the majority of birds would not be assessed by the Official Veterinarian (OV) and/or the Poultry Welfare Officer (PWO) due to the way the transport modules are designed, and the number of birds involved.

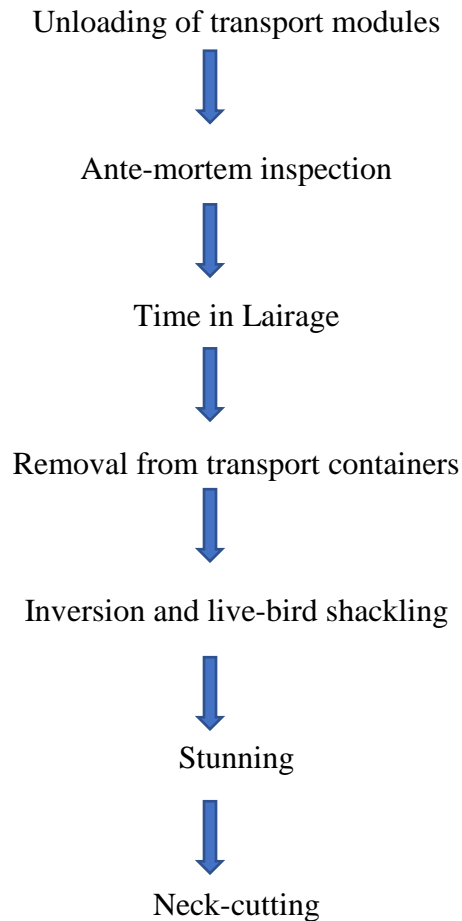
Until recently, water bath stunning was the commonest method of stunning poultry because its installation requires comparatively less capital investment than, say, gas stunning and it is also widely accepted for Halal meat production. A number of authors have previously cited water bath stunning as the most popular method used to stun poultry (1,2,3), although this may still be the case in some parts of the world, the UK has seen a rise in the use of controlled atmosphere stunning in recent years, according to data from the Food Standards Agency (4). Additionally, water bath stunning is the preferred method of stunning for Halal meat production because it is perceived to be reversible, although this is not always the case as birds can receive different magnitudes of current as a result of differences in bird resistance. In addition, the passage of current through the whole body can affect normal cardiac rhythm and possibly result in the death of birds. Lines and others (5) explained that during conventional water bath stunning, electric current is applied between the 'live' electrode in the water bath and passes through the head, body and legs of birds to earth via a stainless-steel shackle. They reiterated the need for the current to be 'large enough' to cause immediate and sustained unconsciousness to prevent the recovery of birds during the period they are bled-out. The passage of current through the head induces brain dysfunction, however, the passage of current through the body and legs does not stun birds, but may affect the heart. A possible advantage of passing electric current through the body, from an animal welfare perspective is that it can affect normal cardiac rhythm and may induce cardiac arrest, which will cause the death of birds thus preventing

recovery during bleeding-out. However, this will mean that such birds (which die as a consequence of stunning) will not meet the rules of Halal meat production. Additionally, the passage of current through the body may result in carcass damage as a result of direct muscle stimulation by the current causing damaging contraction of skeletal muscles, in particular the breast muscles, with resultant damage to blood vessels, and potentially broken bones (6) This can negatively impact profitability of the plant operators. Fuseini et al. (7) highlighted the challenges Halal certification bodies face in removing and rejecting birds that die as a result of stunning under commercial conditions. Zivotofsky and Strous (8) questioned the humaneness of water bath stunning *per se*, as they argued that, in addition to the stress of shackling, the use of a low frequency in the stunning of birds is associated with aggressive muscle contractions which leads to blemishes and broken bones, and stated that, “it is the view of the authors that muscle contractions may be painful should the contraction occur in the absence of an effective stun”. However, many researchers will not share this view because current normally passes through the head and the body simultaneously to cause ‘immediate’ loss of consciousness and muscle contraction. Although direct application of electric current to the body (without stunning) and the accompanying muscle contractions would be painful, by the time the contractions occur, birds should be stunned and rendered insensible to pain, and will not have the capacity to perceive the pain associated with this form of muscle contraction. Aside the welfare lapses of water bath stunning, there are the meat quality issues associated with this method of stunning (9, 10) however, this is outside the scope and focus of this paper.

The objective of this paper is to conduct a review of the literature on the possible comprises to the welfare of poultry during water bath stunning and to examine whether these welfare lapses affect the suitability of poultry meat for consumption as Halal by Muslims.

Arrival at abattoir





2. Neural communication and mechanism of induction of unconsciousness

The application of electric current to the head of birds disrupts neural communication in the brain by initially affecting the ionic balance across neural membranes and by subsequently altering the equilibrium established by neurotransmitters to induce insensibility. During neural communication, brain cells (neurons) interact through the transfer of chemicals (neurotransmitters) from one cell to the other. The cell from which the neurotransmitters are released is called the pre-synaptic neuron and the cell which receives it is called the post synaptic neuron. The microscopic space between the pre-synaptic neuron and the post-synaptic neuron is called the synaptic cleft, it is in the synaptic cleft that neurotransmitters are released, they then bind to receptors on the post-synaptic neuron to complete the transmission. Neurotransmitters are categorised into excitatory amino acid (e.g. aspartate and glutamate) and

inhibitory amino acid (e.g. Gamma amino butyric acid-GABA), these neurotransmitters provide a controlled equilibrium of neural activity under different conditions. Raj (11) pointed out that slight deviations in the balance of excitatory and inhibitory neurotransmitters in the brain can lead to clinical conditions such as depression and arousal in man. The application of electric current through the brain disrupts the excitatory-inhibitory neurotransmitter balance which leads to epileptiform seizures in the brain to induce brain dysfunction and insensibility. This is the basis for the induction of unconsciousness during electrical stunning which results in the inability of animals to respond to the application of a noxious stimuli such as the neck cut at slaughter. Cook et al. (12) measured the release of neurotransmitters in the brain of sheep by applying 1 Amp of current for different durations between 0.1 s and 20 s. When sheep were stunned with 1 Amp, 50 Hz, 500 V for less than 0.2 s, it was unsuccessful in inducing an epileptiform wave pattern in the EEG, whilst the release of aspartate and glutamate were consistent with levels released during arousal. When they increased the time beyond 0.2 s, they successfully recorded epilepsy, as indicated by an epileptiform wave pattern in the EEG, and the levels of aspartate and glutamate recorded were higher than with the short duration. In a third trial, they increased the duration of application to 4 s and observed increased duration of epilepsy and even greater release of both excitatory and inhibitory amino acid neurotransmitters. The work of Cook et al. (1) and others may have formed the scientific basis for the minimum current required to stun sheep as specified in European Council Regulation EC1099/2009, which requires the application of a minimum of 1 Amp of current for not less than 4 s during the stunning of small ruminants.

3. Shortfalls of water bath stunning

Despite being widely used for stunning poultry, many researchers have criticised water bath stunning for its negative impact on bird welfare during the associated processes such as removal from transport containers, inversion and shackling, pain associated with compressing

the legs of birds between metal shackles. During the stunning phase there is the possibility of pre-stun shocks, the possibility of some birds receiving insufficient current to stun them effectively before neck-cutting, and the recovery of some birds prior to neck-cutting or, during bleeding (13-15). The welfare of birds can be compromised if they regain consciousness during the period they are bled-out. Birds may regain consciousness due to being ineffectively stunned or not cutting the appropriate blood vessels in the neck. Gregory and Wotton (16) investigated the effect of different slaughter methods on spontaneous and evoked activity in the brain of chicken and ducks. They found that the time to loss of spontaneous brain activity ranged between 23 and 233 s, and that loss of evoked responses was between 90 and 349 s. The following sections discuss pre-slaughter handling procedures that negatively impact bird welfare during water bath stunning, as well as some of the deficiencies of the stunning system itself.

3.1. Removal from transport containers and shackling

On arrival at the abattoir, birds in their transport containers are unloaded from trucks and conveyed to the point of hanging or, shackling. They are subsequently removed, inverted and hung by their legs from a stainless-steel shackle. Sparrey and Kettlewell (17) reported that the removal and subsequent shackling of birds is likely to be stressful. Debut and others (18) measured the physiological responses of three chicken breeds to three shackling treatments; 10 s of shackling prior to stunning (control group), 2 minutes of shackling and a third treatment where birds were exposed to acute stress (birds kept in a room with a temperature of 35°C and 60% humidity for 3.5 hours) before shackling them for 2 minutes. They found that the level of blood corticosterone (stress hormone) was lower in the control group irrespective of the genotype, in comparison with the other two treatments where birds were shackled for a longer duration. This corroborates the findings of Kannan and others (19). Shackling involves inversion which is an unnatural position of birds, further, birds lack a diaphragm, therefore

inversion can lead to compression of the thoracic cavity by the viscera, which can present breathing difficulties and possibly death. From a Halal perspective, birds that die prior to neck-cutting must be rejected because Muslims are prohibited from eating animals that die before their necks are cut. The time spent between hanging-on and stunning depends on the design of the processing plant, however, UK domestic legislation, the Welfare of Animals at the Time of Killing (WATOK 2015) Regulation stipulates a maximum of 1 minute for broilers and 2 minutes for turkeys. Shackling of birds can also cause significant pain and physical damage to birds (20-23). Gregory and Wilkins (20) carried out a survey of the impact of shackling on the welfare of end-of-lay hens. They sampled a group of hens prior to and after shackling and found that there was a 44% increase in the number of birds that had freshly broken bones. Lines et al. (22) suggested that the negative impact of conventional shackling on bird welfare may be reduced by adopting 3 techniques, two of which are discussed here (see figures 2 and 3). The third technique, head-only electrical stunning of poultry is not of relevance to this review as it is not yet widely adopted.

- Compliance shackles- These simple shackles were designed to reduce the pain caused by conventional shackles on the legs of poultry (figure 2). The leg slots of compliant shackles are flexible to fit different leg sizes, the researchers reported that these shackles were capable of reducing compression of legs in 99% of birds.
- Breast-support conveyors- Breast-support conveyors were developed to avoid birds being fully inverted during shackling, and to support their body weight by using a conveyor which runs beneath the birds so that their breasts could rest on the conveyor (see figure 3). The researchers found that its use significantly reduced the struggling of birds at the point of shackling and it also improved entry to the water bath.

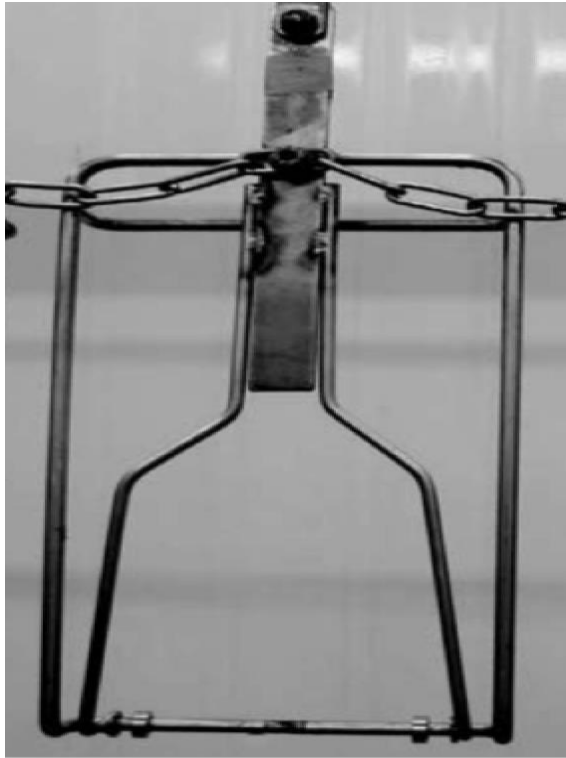


Figure 2. Photo of a compliant shackle (Adapted from Lines et. al., 2012)

3.2.Pre-stun shocks

During water bath stunning, birds may receive potentially painful electric shocks prior to being stunned if the entry to the water bath is wet and not isolated. The occurrence, prevalence and prevention of pre-stun shocks during water bath stunning of poultry has been reported (23-25). For this reason, Annex I (3) of Council Regulation EC1099/2009 stipulates the prevention of pre-stun shocks to protect bird welfare. For birds to be effectively stunned, the head must enter the live water first, if any part of the bird touches the live water before the head, it will lead to electric shocks before the bird is stunned. The incidence of pre-stun shocks may be pronounced if there is increased bird movement on entry to the water bath because the wings may touch the live water before the head. Rao et al. (26) assessed the effect of pre-stun shocks on carcass and meat quality of broilers. They compared the extent of damage to the carcass and meat quality of 500 control birds with 500 birds that were found to have received pre-stun shocks and concluded that pre-stun shocks had a significant effect on carcass downgrading and meat quality. Despite the negative impact of pre-stun shocks on bird welfare and product quality,

Halal authorities who approve stunning continue to accept the procedure despite the religious rules emphasising the need to protect animal welfare. Some Muslims have expressed concern about the animal welfare aspects of water bath stunning in general, although the majority of certifiers still approve it (7).



Figure 3. Breast support conveyor installed to support the weight of birds while they are shackled and inverted (Adapted from Lines et al., 2012)

3.3. Ineffective stunning

Depending on the dimensions of the water bath, several birds are normally immersed in the water bath at any given time. Birds with different resistance will receive varying amount of current, those with high resistance would receive a smaller current in comparison with those with low resistance. This has meant that some birds exit the water bath following currents that are insufficient to effectively stun them, resulting in the stimulation of conscious birds with electric shocks that are likely to be painful. On the other hand, birds with low resistance are likely to receive higher currents which may result in their deaths before neck-cutting, a situation that would make meat from such birds incompatible with Halal. This problem is

exacerbated by the use of constant voltage water bath stunners. The Humane Slaughter Association (HSA) in their online guide on electrical water bath stunning of poultry indicated that despite the shortfalls of constant voltage stunners, they were still widely used in the poultry industry (27). Sparrey and Others (28) described a prototype poultry stunner capable of delivering constant current to ensure that all birds receive the same amount of current. In addition to the variation in bird resistance, the electrical parameters used can also affect the effectiveness of the stun. Raj (11) reported that the use of 105 mA of current at 1500 Hz is less effective than the use of the same current at 50 Hz. Use of high frequency electrical stunning (above 400 Hz) is associated with a shorter duration of unconsciousness, frequently leading to the recovery of birds during bleeding-out. To prevent the recovery of birds and ineffective stunning, it has been suggested that appropriate electrical parameters must be used to induce cardiac arrest (29). Gregory and Wotton (30) successfully induced cardiac arrest in 99% of birds by using higher currents averaging 148 mA per bird at 50 Hz sinusoidal AC. It is worth noting that the induction of cardiac arrest is followed by brain death, this implies that the majority of birds could be technically dead or dying before neck-cutting which means that these birds would not be accepted by the Muslim authorities for Halal meat production. Due to the above problems associated with water bath stunning with regard to animal welfare, many food business operators are switching to the use of controlled atmosphere stunning, usually employing a CO₂ rich atmosphere. The use of controlled atmosphere stunning eliminates pre-slaughter handling as the birds are kept in their crates during the procedure, pre-stun shocks, inversion of birds and ineffective stunning. Further, UK domestic legislation (WATOK 2015) requires animals to be dead before they exit the gas environment, therefore, the immediacy and accuracy of neck-cutting becomes irrelevant to their welfare. However, Halal authorities cannot accept the use of controlled atmosphere as the birds are killed before they receive the neck cut associated with religious slaughter.

4. Compatibility of water bath stunning for Halal meat production

Halal meat is that which is permissible for consumption by Muslims. The rules surrounding animal welfare aspects of Halal slaughter are derived from the Quran (Islamic Holy Book) and the *Hadith* (teachings of the Prophet of Islam). These rules require animals to be alive at the point their necks are cut, although some Muslims also insist that animals must be conscious. There is an extensive literature on animal welfare in Islam (31-34 and others). Available literature point to the fact that the Prophet of Islam was a known animal welfare advocate who consistently reprimanded his companions when they abused animals. It is well documented that the prophet banned some cultural practices in Arabia such as the cutting and consumption of parts of live animals, often considered a delicacy in pre-Islamic Arabia (35). Muslims today are therefore expected to follow the footsteps of the Prophet, but this is not always the case. If Muslims were to strictly follow the guidance for the protection of animal welfare in the religious scriptures, it can be argued that water bath stunning, with its associated lapses in protecting the welfare of animals (outlined above) and the slaughter of animals without stunning [which has been scientifically shown to compromise animal welfare, see (36-37)] could arguably not be approved for Halal meat production. But the majority of Muslims, in trying to follow the footsteps of the Prophet, prefer slaughter without stunning because it was the only method available and used at the time of the Prophet. Additionally, there is no guarantee that all birds stunned using water bath stunners would be alive at the point their necks are cut. It is due to these uncertainties surrounding the reversibility of water bath stunning that some Muslim authorities, such as the UK's Halal Monitoring Committee (HMC) and France's AVS Association have put a blanket ban on all forms of stunning for poultry. However, many animal welfare organisations have insisted that if indeed Islam holds animal welfare in high regard, why would Muslims not approve stunning, a procedure that has been scientifically validated to reduce the pain associated with neck-cutting?

5. Alternative stunning technology

A new head-only electrical stunning system (HOES) was developed by Dutch Vision Solutions in an effort to address some of the shortfalls of conventional water bath stunning. The HOES is a constant current electrical stunning system which delivers constant current control of 275 mA per bird for 1 s followed by a lower immobilising current. Birds that are not effectively stunned, i.e. those that receive less than 240 mA per bird or those that are completely missed, are automatically selected by a secondary system, the Kill Shackle Line (KSL) splitter to be re-stunned. This ensures that the problem of some birds receiving very low current during conventional electrical stunning is eliminated with a combination of the HOES and KSL. Researchers from Wageningen UR Livestock Research tested the efficacy of the HOES at a commercial abattoir with a throughput of 13,500 birds per hour in The Netherlands (38), they concluded that the HOES is capable of improving bird welfare. They successfully stunned over 95% of birds, however, there was significant variation in effectiveness of stunning between the 32 individual stunning units and also between flocks. Additionally, they reported that eye reflexes were absent in 99.3%, 96.8%, 90.3% of birds 30 s, 60 s and 90 s respectively after stunning. However, the majority of birds (95%) recovered from the stun after 120 s. This will appeal to Muslim authorities who approve stunning for Halal meat production as it demonstrates that birds would be alive and recoverable at the point of neck cut. The system has also been reviewed and given positive feedback by the UK's Farm Animal Welfare Committee (FAWC). As a result, at least one commercial abattoir has applied to the UK's Department for Environment, Food & Rural Affairs (DEFRA) for permission to install the system. It must be reiterated that despite improvements in the effectiveness of the stun, birds are still being inverted and shackled when using Dutch Vision Solution's HOES, further, it may require large initial capital investment which will make it less attractive for smaller plants. The HOES should not therefore be considered a panacea for all the shortfalls of conventional water bath stunning,

researchers should continue in their quest to find a system that will address the problems highlighted in this paper.

6. Conclusion

The use of water bath stunning for the slaughter of poultry presents a dilemma from both animal welfare and Halal viewpoints. Processing plant procedures prior to neck-cutting e.g. removal from transport containers, inversion and shackling pose a series of animal welfare concerns. There is also the issue of pre-stun shocks, which are likely to be painful, in addition to the grave concern over the possibility of ineffective stunning of birds with a high resistance and also during the use of high frequency electrical stunning of birds. From a Halal standpoint, there is the possibility that, under certain conditions, birds may die as a consequence of the additive stress of pre-slaughter handling and the use of irreversible electrical parameters. Some of the welfare issues (such as removal from transport containers, inversion, shackling, pre-stun shocks and ineffective stunning) can be prevented by using controlled atmosphere stunning. However, despite the apparent improvements in welfare, controlled atmosphere stunning is incompatible with Halal slaughter because all of birds should be dead as they exit the gas unit, and before the neck cut. The HOES system developed in The Netherlands appears to potentially eliminate the problem of ineffective stunning of birds during conventional water bath stunning, and also avoids cardiac arrest, so may be acceptable to some Muslims for use during Halal meat production as it has also been shown to be reversible. However, the welfare issues associated with removal of birds from transport containers, inversion and shackling still persist with the HOES.

References

1. Cook CJ, Maasland SA, Devine CE, Gilbert KV, Blackmore DK. Changes in the release of amino acid neurotransmitters in the brains of calves and sheep after head-only

- electrical stunning and throat cutting. *Research in Veterinary Science* 1996; 60: 255-261.
2. Bager F, Braggins TJ, Devine CE, Graafhuis AE, Mellor DJ, Tavener A, Upsdell MP. Onset of insensibility at slaughter in calves: Effects of electroplectic seizure and exsanguination on spontaneous electrocortical activity and indices of cerebral metabolism. *Research in Veterinary Science*; 52: 162-173.
 3. Prinz S, Van Oijen G, Ehinger F, Coenen A, Bessei W. Electroencephalograms and physical reflexes of broilers after electrical water bath stunning using an alternating current. *Poultry Science* 2010; 89: 1265-1274.
 4. Food Standards Agency (FSA). Results of 2013 animal welfare survey in Great Britain. <https://www.food.gov.uk/sites/default/files/2013-animal-welfare-survey.pdf>
(Accessed, 12/01/2018).
 5. Lines JA, Raj ABM, Wotton SB, O'Callaghan M, Knowles TG. Head-only electrical stunning of poultry using a water bath: a feasibility study. *Meat and Egg Science* 2011; 52: 432-438.
 6. Wilkins, L.J., Gregory, N.G., Wotton, S.B. and Parkman, I.D. Effectiveness of electrical stunning applied using a variety of waveform-frequency combinations and consequences for carcass quality in broiler chickens. *British Poultry Science*. 1998; 39: 511-518.
 7. Fuseini A, Knowles TG, Hadley PJ, Wotton SB. Halal stunning and slaughter: Criteria for the assessment of dead animals. *Meat Science* 2016; 119: 132-137.
 8. Zivotofsky, AZ, Strous, RD. A perspective on the electrical stunning of animals: Are there lessons to be learned from human electro-convulsive therapy (ECT)? *Meat Science* 2012; 90: 956-961.

9. Veerkamp CH. What is the right current to stun and kill broilers? *Poultry* 1998; 4: 30-31.
10. Gregory NG, Wilkins LJ. Effect of ventricular fibrillation at stunning and ineffective bleeding on carcass quality defects in broiler chickens. *British Poultry Science* 1989; 30:825-829.
11. Raj ABM. A critical appraisal of electrical stunning in chickens. *World's Poultry Science Association* 2003; 59:89-98.
12. Cook CJ, Devine CE, Gilbert KV, Smith DD, Maasland SA. The effect of electrical head-only stun duration on electroencephalographic-measured seizures and brain amino acid neurotransmitter release. *Meat Science* 1995; 40: 137-147.
13. Gregory NG, Wotton SB. Poultry slaughtering procedures. Papers Paper #2-18 European Meeting of Meat Research Workers 1985. Albena, Bulgaria. pp. 87-91.
14. Raj ABM. Welfare during stunning and slaughter of poultry. *Poultry Science* 1998; 77: 1815-1819.
15. European Food Safety Authority (EFSA). The welfare aspects of the main systems of stunning and killing applied to commercially farmed deer, goats, rabbits, ostriches, ducks, geese and quail. *EFSA Journal* 2006; 326: 1-18.
16. Gregory NG, Wotton SB. Effect of slaughter on the spontaneous and evoked activity of the brain. *British Poultry Science* 1986; 27:195-205
17. Sparrey JM, Kettlewell PJ. Shackling of poultry: is it a welfare problem? *World's Poultry Science Association* 1994; 50: 167-176.
18. Debut M, Berri C, Arnould C, Guemene D, Sante-Lhoutellier V, Sellier N, Baeza E, Jehl N, Jago Y, Beaumont C, Le Bilhan-Duval E. Behavioural and physiological responses of three chicken breeds to pre-slaughter shackling and acute stress. *British Poultry Science* 2005; 46: 527-535.

19. Kannan G, Heath JL, Wabeck CJ, Mench JA. Shackling of broilers: effect on stress responses and breast meat quality. *British Poultry Journal* 1997; 38: 323-332.
20. Gregory NG, Wilkins LJ. Broken bones in domestic: handling and processing damage in end-of-lay hens. *British Poultry Science* 1989; 30: 555-562.
21. Gentle MJ, Tilston VL. Nociceptors in the legs of poultry: Implications for pain in pre-slaughter shackling. *Animal Welfare* 2000; 9:227-236.
22. Lines JA, Berry P, Cook P, Schofield CP, Knowles TG. Improving the poultry shackle line. *Animal Welfare* 2012; 21:69-74.
23. Wotton SB, Gregory NG. How to prevent pre-stun shocks in water bath stunners. *Turkeys* 1991; 39: 15-30.
24. Raj, ABM, Tserveni-Gousi A. Stunning methods for poultry. *World's Poultry Science Journal* 2000; 56:292-304.
25. Humane Slaughter Association (HSA). Prevention of pre-stun shocks in water baths. Technical Note. HSA 2006; HSA Wheathampstead, Herts, UK
26. Rao MA, Knowles TG, Wotton SB. The effect of pre-stun shocks in electrical water-bath stunners on carcass and meat quality in broilers. *Animal Welfare* 2013; 22:79-84.
27. Humane Slaughter Association (HSA). HSA online guide-electrical water bath stunning of poultry 2016. <https://www.hsa.org.uk/downloads/publications/hsaonlineguidewaterbathpoultryapril2016.pdf> (Accessed, 31/05/2018).
28. Sparrey JM, Kettlewell PJ, Paice MER, Whetlor WC. Development of a constant current water bath stunner for poultry processing. *Journal of Agricultural Engineering Research* 1993; 56: 267-274.

29. Grandin T. Cardiac arrest stunning of livestock and poultry. In *Advances in Animal Welfare*: Fos MW, Mickley LD ed. Martinus Nijhoff Publishers, The Hague, The Netherlands.
30. Gregory NG, Wotton SB. Effect of electrical stunning on the electroencephalogram in chicken. *British Veterinary Journal* 1987; 143: 175-183.
31. Fuseini A, Knowles TG, Hadley PJ, Wotton SB. Food and companion animal welfare: The Islamic perspective. *CAB Reviews* 2017 (*In Press*).
32. Abdul Rahman, S., & Aidaros, H. Islam and animal welfare with special reference to cruelty to animals during transport and slaughter. *Journal of Commonwealth Veterinary Association*. 2012; 28, 27-30
33. Haque, N. and Masri, B.A. The principles of animal advocacy in Islam: Four integrated recognitions. *Society and Animals*, 2011; 19, 279-290.
34. Fuseini A, Wotton SB, Hadley PJ, Knowles TG. The compatibility of modern slaughter techniques with halal slaughter: a review of the aspects of 'modern slaughter' methods that divide scholarly opinion within the Muslim community. *Animal Welfare* 2017; 26:301-310.
35. Masri BA. *Animal welfare in Islam, Revised Edition*. The Islamic Foundation: Leicester, UK.
36. Gregory NG, Fielding HR, von Wenzlawowicz M, von Hollenben K. Time to collapse following slaughter without stunning in cattle. *Meat Science* 2010; 85: 66-69.
37. Farm Animal Welfare Council (FAWC). Report on the welfare of livestock when slaughtered by religious methods. HMSO Reference Book 262 London, UK; 1984 p. 49.
38. Gerritzen MA, Van Hattum T, Reimert H, Efficacy of the Dutch Vision high-low electrical head-only poultry stunner. *Livestock Research Report* 2015; 442: 23.