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Review

Stunning and animal welfare from Islamic and scientific perspectives

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ABSTRACT

The transformation of an animal into pieces fit for human consumption is a very important operation. Rather than argue about halal slaughter without stunning being inhumane or stunning being controversial from the Islamic point of view, we discuss slaughter, stunning and animal welfare considering both Islamic and animal welfare legislation requirements. With the world Muslim population close to two billion, the provision of halal meat for the Muslim community is important both ethically and economically. However, from the animal welfare standard point of view, a number of issues have been raised about halal slaughter without stunning, particularly, about stressful methods of restraint and the latency of the onset of unconsciousness. This paper sets out to, discuss the methods of stunning that are acceptable by Islamic authorities, highlight the requirements for stunning to be acceptable in Islam and suggest practical ways to improve the humanness of slaughter.

Contents

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1. Introduction

Debate about proper treatment of animals first emerged as early as the beginning of the sixth century BC, but perhaps it was in the late twentieth century that science was called upon to clarify the issues and guide the resulting reforms (Fraser, 2008). Religious slaughter has been one controversial issue at the heart of these debates. The study of animal welfare developed in response to certain kinds of ethical problems and historical or cultural context characterized by certain historically and culturally conditioned beliefs and values (Fraser, 2008).

Slaughter is probably the most important operation in the transformation of an animal into pieces fit for human consumption. This crucial moment of killing is governed by strict regulations related to food hygiene and safety, working conditions and animal welfare (Bergeaud-Blackler, 2007).

Being humane is an attitude of heart and mind, empathy and understanding, and not simply a legal or moral injunction (Fox & Mickley, 1984). According to the Universal Declaration of Animal Rights that was proclaimed in Paris, France in 1978, all animal life has the right to be respected and if it is necessary to kill an animal, it must be instantaneous, painless and cause no apprehension (Chapouthier & Nouët, 1998). Humane slaughtering concerns being sympathetic for the animals being killed for meat production through minimizing animal suffering and respect for animals' intrinsic worth. This is probably what Prophet Muhammad (peace be upon him) preached when he said: "*Allah calls for mercy in everything, so be merciful when you kill and when you slaughter; sharpen your blade to relieve its pain.*" (Al-Qaradawi, 1994). Islam places great emphasis on humane treatment of animals, especially before and during slaughter. Some of the conditions include giving the animal proper rest and water, avoiding conditions that create stress, not slaughtering an animal in front of others of its kind, not sharpening the knife in front of the animals, using a very sharp knife to slit the throat, to mention but a few. It is important to acknowledge that Islam respects the intrinsic worth of animals and teaches animal welfare. Allah mentions in the holy Quran;

> "*And there is no creature on [or within] the earth or bird that flies with its wings except [that they are] communities like you*" Al An-am, 6:38.

In a hadith narrated by Abdallah bin Amru, Prophet Muhammad (peace be upon him) said;

> "*Whoever is kind to the creatures of God, is kind to himself.*" (Masri, 1989).

It is reported by Ibn Sirin that Hazrat 'Omar once saw a man denying a sheep, which he was going to slaughter, a satiating measure of water to drink. He gave the man a beating with his lash and told him: "*Go, water it properly at the time of its death, you knave!*" (Masri, 1989).

Head only electrical stunning, non-penetrative captive bolt stunning and water bath stunning of poultry have been approved by many Islamic authorities, as long as the method is reversible. Appropriate procedures and related minimum requirements are recommended for different species such that slaughter can be done without causing avoidable pain, suffering and distress. The stun to neck cut time is a critical point for the Shariah requirement of the animal being alive at the time of slaughter and the welfare requirement of the animal being bled while still unconscious. A number of issues have been raised about halal slaughter without stunning, particularly, about stressful methods of restraint and the slow rate at which animals lose consciousness as this lengthens the time the animal could experience pain or distress following the cut. The main objective of this paper is to describe the main slaughtering and stunning methods under commercial slaughter conditions that meet both Islamic and other legal requirements.

2. Why do Muslims practice halal slaughtering?

According to the Department of Islamic Development Malaysia (JAKIM) (2011), halal slaughtering process of an animal involves restraining, stunning (if used) and severing of trachea, esophagus and both the carotid arteries and jugular veins. In Shariah law, slaughtering is not a normal matter in which humans act independently as they wish, but it is rather a matter of worship which Muslims must abide by in its provisions. The holy Quran has stipulated specific requirements for the slaughter of religiously acceptable animals. In surat Al-Baqarah, Allah mentions what is forbidden for consumption by the believers.

> "*He has forbidden you only the Maytatah (dead animals), and blood, and the flesh of swine, and that which is slaughtered as a sacrifice for others than Allah (or has been slaughtered for idols, etc., on which Allah's name has not been mentioned while slaughtering*" (Al-Baqarah 2:173).

In surat Al-Maidah, Allah mentions what is lawful for consumption by the believers.

> "*They ask you (O Muhammad S.A.W) what is lawful for them (as food). Say: "Lawful unto you are At-Tayibat [all kind of Halal (lawful-good) foods which Allah has made lawful (meat of slaughtered eatable animals…"*" (Al-Maidah 5:4).

In a number of verses, Allah reminds the believers to mention His name at the time of slaughtering.

- "*And mention the Name of Allah … over the beast of cattle that He has provided for them (for sacrifice), at the time of their slaughtering by saying: (Bismillah, Wallâhu-Akbar…)*" (Al-hajj 22:28).
- "*And for every nation We have appointed religious ceremonies, that they mention the Name of Allah over the beast of cattle that He has given them for food…*" (Al-hajj 22: 34).
- "*And the Budn (cows, oxen, or camels driven to be offered as sacrifices by the pilgrims at the sanctuary of Makkah) We have made for you as among symbols of Allah, there in you have much good. So mention the Name of Allah over them when are they are drawn up in lines (for sacrifice)*" (Al-hajj 22:36).

Believers are also reminded not to eat that over which Allah's name has not been mentioned.

> "*And why should you not eat of that meat on which Allah's Name has been pronounced (at the time of slaughtering the animal), while He has explained to you in detail what is forbidden to you…*" (Al-An'âm 6:119).

It is important for scientists to understand that the main reason for the observance of the Islamic faith is to follow the Divine Orders. Allah reminds the believers in the Holy Quran in the following verse;

> "*O ye who believe! Eat of the lawful things that We have provided you with, and be grateful to Allah, if it is indeed He whom you worship.*" (Al-Baqarah 2:172).

A number of Muslims may not have accepted stunning at first glance because of the fear to fall in the doubtful things. In a hadith narrated by Bukhari and Muslim, Prophet Muhammad (peace be

upon him) said: "*Both legal and illegal things are clear but in between them there are doubtful (suspicious) things and most of the people have no knowledge about them. So whoever saves himself from these suspicious things saves his religion and his honour. And whoever indulges in these suspicious things is like a shepherd who grazes (his animals) near the Hima (private pasture) of someone else and at any moment he is liable to get in it. (O people!) Beware! Every king has a Hima and the Hima of Allah on the earth is His illegal (forbidden) things.*" (Al-Qaradawi, 1994).

Scientific study of animal welfare is important so that decisions are made on factual rather than emotional grounds. If animal welfare is to be compared or evaluated in particular situations, it must be assessed in an objective way (Dollins, 1999). Given the importance of halal slaughter to Muslims, it is important that scientists must be absolutely objective when evaluating this practice from an animal welfare standpoint.

3. Welfare concerns about halal slaughter without stunning

The welfare of animals is protected by Section 2 of the 1958 Humane Slaughter Act, which requires that all animals be rendered insensible to pain before being shackled, hoisted or cut. However, the law permits slaughtering in accordance with ritual requirements of any religious faith that prescribes a method of slaughter whereby the animal suffers loss of consciousness by severance of the carotid artery with a sharp instrument (College of law, 2011). The prescribed Islamic method of slaughter involves killing the animal by cutting the jugular vein, carotid artery, trachea and esophagus with a sharp knife by a single swipe in order to incur less pain. Welfare issues put forward by individuals concerned about animal welfare during slaughter without stunning include stress of the restraint, whether the cut is painful and whether the animal experiences undue distress while bleeding, and latency of onset of complete insensibility (Gibson et al., 2009; Grandin, 2010b, chap. 9; Grandin & Regenstein, 1994; Gregory, 2005; Ndou, Muchenje, & Chimonyo, 2011). There are concerns that in some countries, slaughter plants use very stressful methods of restraint such as shackling and hoisting fully conscious animals with one rear leg. Stressful or painful methods of restraint cause bruises or injures and may mask the animal's reactions to the throat cut (Grandin & Regenstein, 1994). There are further concerns that halal slaughter without stunning compromises animal welfare, particularly, about the rate at which animals lose consciousness as this influences the length of time the animal could experience pain or distress following the cut (Gregory, Fielding, Von Wenzlawowicz, & Von Holleben, 2010). Gregory (2008) argued that when animals are slaughtered without stunning, some take long to lose brain function and die. Ndou et al. (2011) and Gregory (2005) further argued that cutting the neck in an anesthetized state is likely to involve physiological events that are likely to be a sense of shock, compared to an electric shock. A study conducted in New Zealand by Gibson et al. (2009) demonstrated that there is a period following slaughter when ventral neck incision represents a noxious stimulus.

Studies about how long it takes animals to lose consciousness during slaughter without stunning have yielded controversial results. Assessment of time to brain failure or evoked activity using electroencephalogram (EEG) or electrocorticogram (ECG) showed that calves lost brain function promptly (Gregory & Wotton, 1984; Nangeroni & Kennett, 1963; Schulze, Schultze-Petzold, Hazem, & Gross, 1978). Contrary, other studies showed that some animals take a relatively long time to lose consciousness or develop changes in spontaneous or evoked activity (Bager, Braggins, Devine Graafhuis, Mellor, & Tavener, 1992; Blackmore, 1984; Daly, Kallweit, & Ellendorf, 1988; Gregory et al., 2010; Newhook & Blackmore, 1982). Recently, Gregory et al. (2010) studied the time to collapse following slaughter without stunning in 174 cattle which were restrained in the upright position and then released immediately from the restraint following the halal cut. Results showed that the average time to final collapse for all the cattle was 20 s (sd ± 33). In 8% of the animals, time to final collapse was greater than 60 s. Fourteen percent of the cattle collapsed and stood up again before finally collapsing. In the same study, swelling of the carotid arteries for both the cephalic and cardiac severed ends was examined. Seventy-one percent of the cattle that took more than 75 s to collapse had false aneurysms in the cardiac ends of the severed carotid arteries. The authors associated failure to collapse within 60 s with swelling of the cephalic ends of the carotid arteries and recommended that the results of their study provide an incentive for religious slaughter authorities to manage the problem of protracted consciousness in cattle. False aneurysms develop when a severed artery end retracts within its surrounding connective tissue sheath (Gregory, Shaw, Whitford, & Patterson-Kane, 2006), the impact of which is delayed onset of unconsciousness as during the intervening period nociceptive neuronal signals can reach the brain (Gibson et al., 2009; Gregory et al., 2010). Gregory et al. (2008) showed that when cattle are slaughtered by the halal method, their carotid arteries are prone to developing false aneurysms at the severed cardiac ends.

Blood flowing from the severed end may impregnate the adventitia and the artery end may become sealed as the adventitia swells with blood (Gregory, Von Wenzlawowicz, & Von Holleben, 2009). Arresting bleeding in such a way might result in the continuation of blood flow to the brain via the collateral vertebro-basilar plexus which is particularly well developed in cattle (Anil, McKinstry, Gregory, Wotton, & Symonds, 1995). The continuity of blood flow to the brain via the collateral vertebro-basilar plexus depends on how soon after the cut the severed ends of the carotid arteries become occluded (Gregory, Schuster, Mirabito, Kolesas, & McManus, 2012). Gregory et al. (2012) have assessed time to onset of arrested blood flow and the size of false aneurysms in the severed carotid arteries in 126 cattle during halal slaughter without stunning. The average time to early arrested blood flow has been found to be 21 s on average, accompanied by enlargement with false aneurysms which occlude the arteries.

Aspiration of blood into the lungs is yet another welfare concern of halal slaughter without stunning (Grandin, 2010b, chap. 9). Gregory et al. (2009) examined bovine respiratory tracts of 124 animals for blood following halal slaughter without stunning. Fifty eight percent and 69% of the cattle were found to have blood lining the inner aspect of the trachea and the upper bronchi, respectively (Fig. 1). They concluded that concerns about suffering from airway irritation by blood could apply in animals that are slaughtered without stunning or do not lose consciousness rapidly while blood is present in the respiratory tract. Although it is claimed that aspiration of blood into the upper respiratory tract and lungs causes suffering during slaughter without stunning (Gregory et al., 2009; Von Wenzlawowicz & von Holleben, 2007; Webster, 1994), there may be no suffering since afferent signals activated by lung irritants are conveyed by neurons in the vagus nerves (King, 1999), and these are severed during halal slaughter.

4. Importance of stunning

Stunning before slaughter can be defined as a technical process subjected to each single animal to induce unconsciousness and insensibility in animals so that slaughter can be performed without avoidable fear, anxiety, pain, suffering or distress (European Food Safety Authority (EFSA), 2006). Stunning was originally performed as a method of animal immobilization to allow easier and safer manipulation of the animal (Bergeaud-Blackler, 2007), particularly, for personnel handling large animals in order to achieve efficient cutting of the blood vessels in the neck. However, in the recent years, it has been viewed primarily from an animal welfare perspective as a means to minimize the pain and suffering associated with slaughter (Fletcher, 1999). The 1958 Humane Slaughter Act requires that all USDA inspected animals be rendered insensible to pain before exsanguination. Stunning should produce a rapid onset of stress-free insensibility for a duration sufficient to allow the animal to remain unconscious

Source: Gregory et al. (2009a)

Fig. 1. Cattle tracheas examined after halal slaughter, showing no blood (lower photograph) and fine blood-tinged foam (upper photograph).

until death, either from the results of the stun itself or due to subsequent killing operations such as neck cutting during slaughter (Fletcher, 1999). Therefore, from a welfare point of view, the basic purpose of stunning is to render the animal unconscious and insensible so that it may not feel pain during slaughter (Anil, Raj, & McKinstry, 2000; Craig & Fletcher, 1997; Limon, Guitian, & Gregory, 2010; Öneç & Kaya, 2004).

5. Conditions for stunning to be accepted in Islam

The primary sources of Islamic law are the Holy Quran and Hadith (the practice of Prophet Muhammad peace be upon him). The basic principles of the Islamic law remain definite and unaltered. However, their interpretation and application may change according to two other sources of jurisprudence, namely Ijma (a consensus of legal opinion) and Qiyas (reasoning by analogy) to suit the time, place, and circumstances (Che Man & Sazili, 2010, chap. 11; Regenstein, Chaudry, & Regenstein, 2003). Consequently, Muslim scholars have adopted nonlethal methods of stunning to meet the legal requirements for humane slaughter regulations. However, for stunning to be accepted in Islam, there are three pre-requisites that must be fulfilled. Firstly, the stunning equipment must be used under the control of a trained Muslim supervisor or slaughter man and should be periodically monitored by a competent Islamic authority or halal certification authority (JAKIM, 2011; Malaysia Standard MS 1500, 2004, 2009). Secondly, the stunning should be done so temporarily that it must neither kill (Masri, 1989; Riaz & Chaudry, 2004) nor cause permanent injury to the animal (JAKIM, 2011; MS1500, 2004, 2009). The stunning should be reversible. Lastly, equipment used to stun pigs must never be used for halal animals (Khawajah, 2001; MS1500, 2004). An overview of Shariah requirements for stunning is given in Table 1.

Since the 1980s when an electrical stunning apparatus that met Muslim standards of regaining consciousness was first developed in New Zealand, many Islamic authorities in different countries have accepted pre-slaughter stunning. Head-only electric stunning prior to halal slaughter is used in almost all cattle, sheep and goat slaughter plants in New Zealand and Australia. With the current advance in technology, pre-slaughter stunning can be carefully employed to ensure production of halal meat while maintaining maximum animal welfare standards. In order to achieve maximum efficiency, the equipment must be well designed and slaughter men must be well trained so as to operate the equipment correctly. It is the responsibility of management to ensure that operators are competent, the methods are appropriate and effective and the equipment are well maintained and regularly checked by a competent authority (OIE, 2008, chap. 7.5). Both well designed equipment and trained employees are necessary for maintaining a high standard of animal welfare during slaughter (Grandin, 2006). Employees working with live animals need to be systematically trained with respect to animal welfare. They need to be trained in welfare aspects of the most relevant production steps of slaughterhouses such as unloading animals to lairage facilities, handling animals from lairage to stunning facilities, restraining, stunning, hoisting and bleeding. Training of slaughterhouse staff improves the employees' attitude towards the animals and minimizes incidences of inefficient stunning (Grandin, 2010b, chap. 9). The management(s) of the slaughterhouses needs to implement a plan of control for animal welfare aspects based on Hazard Analysis Critical Control Points (HACCP) or a similar quality assurance system. A special employee should be assigned the responsibility of overseeing animal welfare. Implementation of a quality assurance scheme with an emphasis on animal welfare and the presence of an animal welfare officer employed by the slaughterhouse are considered the two most beneficial operational procedures in terms of animal welfare (Food Chain Evaluation Consortium (FCEC), 2007).

Table 1
Shariah requirements for stunning.
Source: Malaysian protocol for the halal meat and poultry productions

i) The method used should be reversible stunning and should not kill or cause permanent physical injury to the animal.
ii) The person who is responsible for the stunning operation (operation, control and monitoring) should be trained in its use and preferably a Muslim.
iii) The Muslim halal checker should verify that the stunning operation is conducted according to the approved methods.
iv) The animal to be slaughtered should be alive or deemed to be alive at the time of slaughter.
v) If the animal is found dead due to the stunning procedure, the slaughter man should identify and remove it from the halal system.
vi) The phrase "*Bismillah Allahu Akbar*" must be invoked by a Muslim slaughterman immediately before slaughtering.
vii) The bleeding should be spontaneous and complete.
viii) Scalding of poultry and carcass dressing of ruminants should only begin after the animal has been deemed dead from bleeding.
ix) The equipment or tools used should only be dedicated to stunning halal animals and should never be used for stunning animals which are considered haram by Shariah law.
x) If the equipment that were once used for haram animals are to be converted to use in the stunning of halal animals, they (equipment) should be ritually cleansed. The procedure should be supervised and verified by a competent Islamic authority.
xi) The premises for stunning of halal animals should be physically segregated from other premises that deal with haram animals.

6. Methods of stunning accepted in Islam

Pre-slaughter stunning can be accomplished through mechanical, gas/chemical and electrical stunning methods (EFSA, 2006; Gregory, 2005; McNeal, 2002; OIE, 2008, chap. 7.5; Zivotofsky & Strous, 2012) but not all these methods have been approved for halal slaughter. The main stunning method used in the EU to slaughter cattle is the penetrating captive bolt. However, this method is not halal compliant. It had even been implicated in transmitting bovine spongiform encephalopathy (BSE), particularly, the risk of dissemination of Central Nervous System (CNS) material via blood circulation to edible organs/tissues in cattle (Anil, Love, Helps, & Harbour, 2002). Non-penetrative stunners are accepted for use in halal slaughtering of cattle and buffalo but the stunner must neither penetrate nor break the head. Any injury caused must not be permanent and the animal's skull should be checked after skinning for any permanent injuries (JAKIM, 2011; MS1500, 2004, 2009). Percussive bolt stunning is acceptable by Islamic authorities because the bolt does not invade the brain, thus there is less likelihood of intracerebral hemorrhage. This stunning is also reversible. To maintain the required bolt velocities, the guns should be regularly cleaned. This will prevent the accumulation of carbon and silica in the breech, which would otherwise increase the size of the expansion chamber through limiting the return of the bolt to its correct position thus reducing the power of subsequent shots (Gregory, 2007). Although gas mixtures of carbon dioxide and argon or nitrogen are currently being used in some countries to stun pigs (haram animals), lamb and poultry, the method is not permitted prior to halal slaughter. Electrical stunning

can be performed either by head-only stunning or by head-to body stun involving cardiac arrest for killing. Head-to body stunning is not halal compliant. Head-only-stunning is the only approved electrical stunning method for halal slaughter in all animals. Electrical stunning of poultry is acceptable using water bath stunners only (MS1500, 2004, 2009). Stunning must not damage the heart or brain or cause physical disability or death. The strength of current used should be supervised by a trained Muslim slaughter man and periodically monitored by competent Islamic authority or halal certification authority. Guide lines for stunning parameters (current and time) are given in Table 2.

The rate at which unconsciousness sets in is determined by current flowing through the brain (Grandin, 2010b, chap. 9; María, López, Lafuente, & Mocé, 2001). To facilitate uninterrupted application of the electrical current to effectively stun any species, the animal should be suitably restrained; electrodes should be placed so that the brain is in the current path, good electrical contact should be maintained between the tongs and the head (taking account of animal hair and wool) and electrical current should be applied once (EFSA, 2004a). Thus, the voltage must be high enough to overcome the total electrical resistance in the pathway between the electrodes (i.e., electrode material, skin, thickness and porosity of skull, brain tissue and distance between the electrodes) such that the required amount of current can flow within the shortest possible time (FCEC, 2007). During the stunning, good electrical contact must be maintained between the electrodes and the head (María et al., 2001). Correct placement of the electrodes is important to ensure the current passes the brain of almost all (99%) of the animals (Grandin, 2010b, chap. 9). This implies that the design and construction of the electrodes and the pressure applied during the initiation of the stun are important to delivering the current. Verifying electrical parameters (i.e. current, voltage, and frequency) is a necessary procedure for both animal welfare and meat quality reasons. The best practice would be logging or registering of the stunning parameters as this would assist regulatory bodies during auditing. The simplest way to evaluate a stunner is to test its ability to induce the tonic (rigid, still phase) followed by the clonic spasms (paddling, kicking phase) of an epileptic seizure (Grandin, 2010b, chap. 9). It is recommended that the stunning equipment be tested before application on animals using appropriate resistors or dummy loads to ensure that the power output is adequate to stun animals (OIE, 2008, chap. 7.5).

There are two important critical control points in this method. From the Islamic standard point of view, the current supplied should only be adequate to render the animal unconscious for a short time, that is, the animal should be able regain consciousness. Whereas from the welfare standard point of view, the stun to neck cut time should be so short that the animal's neck is cut before it regains consciousness. Both the amount of current supplied and the stun to neck cut time are important parameters in determining the effectiveness of the stunning. These should be closely monitored. Thus good design and maintenance of equipment as well as employee training and supervision are vital.

Table 2
Guideline parameters for electrical stunning.
Source: Halal food—production, preparation, handling and storage standards—general guidelines. MS 1500:2004. Pp.12.

Type of stock	Current (A)	Duration (s)
Chicken	0.25–0.5	3.00–5.00
Lamb	0.50–0.90	2.00–3.00
Goat	0.70–1.00	2.00–3.00
Sheep	0.70–1.20	2.00–3.00
Calf	0.50–1.50	3.00
Steer	1.50–2.50	2.00–3.00
Cow	2.00–3.00	2.50–3.50
Bull	2.50–3.50	3.00–4.00
Buffalo	2.50–3.50	3.00–4.00
Ostrich	0.75	10.00

7. Halal compliant stunning methods for different animals

After designing the slaughterhouse, it is important to first test the stunning apparatus for compliance with halal standards. Reversibility of the stunning should be verified before massive commercial production commences. Observation of the animal's behavior is a simple method that can be used to assess the effectiveness of stunning (Gregory, 1998). Depending on the method and species involved, animals show typical behavior patterns and physical reflexes during and immediately after stunning (EFSA, 2004a). These can be used to monitor the effectiveness of stunning under commercial conditions. The identification of rhythmic breathing movements indicates the first stages of recovery and is therefore an essential measure for monitoring effectiveness of the stunning treatment (Anil, Raj, & McKinstry, 1998; EFSA, 2004a; Gregory, 1998; María et al., 2001; Velarde et al., 2002) and the major determinant of stun–neck cut time. Rhythmic breathing immediately after stunning shows that stunning was ineffective. Other behavioral indicators of regaining consciousness include corneal reflex which can be elicited by touching the cornea of the open eye with a feather, fingertip or pencil, response to painful stimuli such as repeated nose prick with a hypodermic needle and attempts to raise the head. Another good measure for determining insensibility is natural spontaneous blinking that looks like a live animal in the lairage. Stunning is not effective if either natural spontaneous blinking or vocalization (bellows) occurs (Grandin, 2010b, chap. 9). It is not only a requirement by halal slaughter, but also humane slaughter regulations that carcass dressing and further processing procedures like electrical stimulation should commence only after the animal's death and completion of bleeding. It is preferred that all stunning methods should only be used by properly trained, skilled, and licensed personnel.

8. Halal compliant stunning methods for cattle

Of all species, cattle take long to lose consciousness after neck cutting without prior stunning (Bager et al., 1992; Daly et al., 1988). This is attributed to vertebral arteries (which are protected by the foraminae of the cervical vertebrae). These are not cut and continue to supply blood to the forebrain via the vertebral–occipital anastomosis, the vertebral–maxillary anastomosis and carotid rete. Additionally, severing the common carotid arteries may cause a constriction and narrowing of these arteries (carotid occlusion) which retards bleeding and consequently prolongs the time to loss of consciousness in calves (Anil et al., 1995). The main methods used to stun adult cattle and calves include penetrating captive bolt stunning, non-penetrating captive bolt stunning and electrical stunning. Penetrating captive bolt stunning is not halal compliant.

9. Non-penetrating captive bolt stunning

The non-penetrating captive bolt gun has a mushroom-headed steel bolt which is powered either by air or a cartridge causing sufficient force to initiate trauma to the cortex without penetrating the skull. To ensure effective stunning in adult cattle, frontal application (between the two horns) of the non-penetrating captive bolt stunner is encouraged (Lambooij, 1981). The stunner should be applied to the front of the head and perpendicular to the bone surface (OIE, 2008, chap. 7.5). The air should be sufficiently compressed or the cartridge chosen should be able to produce sufficient velocity to stun the animal. The requirements for halal compliant pneumatic percussive stunning of animals are given in Table 3.

The operator should observe whether the animal collapses immediately and does not attempt to stand, the body and muscles of the animal become tonic (rigid) immediately after the shot, normal rhythmic breathing stops and the eyelids are open with the eyeballs facing straight ahead and not rotated as signs of an effective stun (EFSA, 2004b; OIE, 2008, chap. 7.5). The duration of unconsciousness depends on the animal

Table 3
Requirements for the non-penetrative captive bolt stunning.
Source: Malaysian protocol for the halal meat and poultry productions.

- The animal should be adequately restrained, so that the operator can place the device at the correct site on the head (in order to give an accurate stun).
- The heads of animal to be stunned should be held still before the stunner can be applied.
- The air pressure that powers the stunner should not be more than 225 psi and should be kept to the minimum required to stun the animal.
- The head of the stunner should be slightly convex or flat.
- There should be a protective collar around the head so that the head does not protrude more than 3 mm beyond it.
- The center of the stunner should be in contact with the animal at a point of intersection of lines drawn from the medial corners of the eyes and the base of the ears.
- The stunner should be applied so that the head of the stunner is parallel to the frontal bone.
- The animal should be stunned once. In case another stun is required; the animal should be identified as non-halal.

and the impact energy. Blackmore (1979) observed that corneal reflex on average returned within 20 s and rhythmic breathing returned within 35 s. These observations seem to suggest the stun–neck cut time should be limited to less than 20 s. Non-penetrating captive bolt may not be effective on livestock with thick matted hair on their forehead. It is advisable to carry out thoracic sticking immediately after the neck cut to avoid animals regaining consciousness (Anil et al., 1995). The main drawback of non-penetrating captive bolt stunning is that the method is not always effective for all types of animals as when the skull is immature (calves), bones may be crushed and the impact may be insufficient. While in very thick skulls (bulls), the power of the gun may be insufficient (EFSA, 2004a). Finnie (1995) observed that animals stunned using non-penetrative captive bolt stunner had a depressed fracture of the frontal bone and widespread subarachnoid hemorrhage, particularly beneath the impact site, in the temporal and frontal lobes, and around the brainstem as well as petechial hemorrhage in the basal ganglia and thalamus. Blackmore (1979) and Lambooij (1981) had earlier reported that non-penetrating captive bolt stunning was accompanied by gross brain hemorrhage in some calves. Therefore, a Muslim head checker (he should be a practicing Muslim, technically competent, registered, trained and supervised by the Halal Certification Body) should assess skull damage, identify/label, isolate and record the related non-compliance carcasses if any. Acceptable and unacceptable skull damages are shown in Fig. 2.

10. Head-only electrical stunning

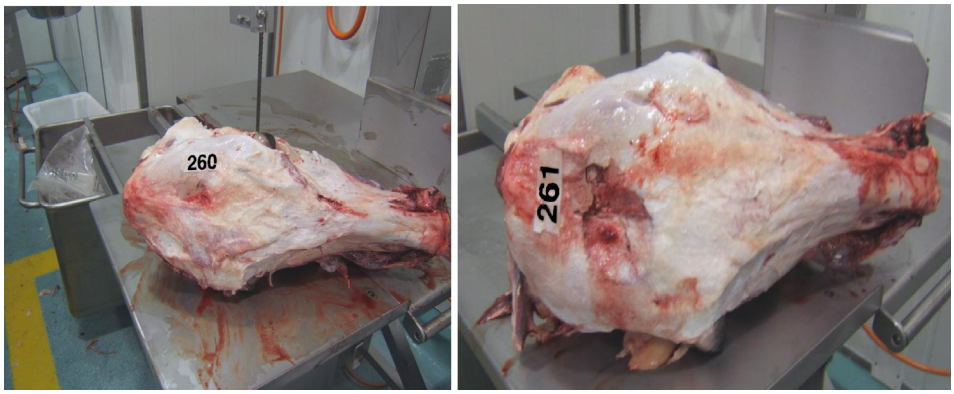
The amount of current applied depends on the animal. Currents of 0.5–1.5 A for 3 s, 1.5–2.5 A for 2–3 s, 2–3 A for 2.5–3.5 s and 2.5–3.5 A for 3–4 s, is recommended for calves, steers, cows and bulls, respectively (MS1500, 2004, 2009). The tongs can either be manually placed across the head, with an electrode behind one eye and another behind the contralateral eye or front of the ear (Schatzmann & Jäggin-Schmucker, 2000) or automatically by purpose-built devices. Unconsciousness lasts between 20 and 100 s, as measured by resumption of normal breathing (Anil et al., 1995; Bager, Shaw, Tavener, Loeffen, et al., 1990; Bager et al., 1992; Blackmore & Newhook, 1982, Devine, Tavener, Graafhuis, & Gilbert, 1987; Devine et al., 1986, Gregory, Anil, McKinstry, & Daly, 1996; Lambooy and Spanjaard, 1982). According to these authors, neck cutting should be carried out within 12 and 23 s after the stun for calves and cattle respectively. Rapid neck cutting and chest sticking after stunning will guarantee that animals do not recover before death ensues through blood loss (Anil et al., 1995). Head-only electrical stunning often results in uncontrolled kicking movements (tonic–clonic seizures) (Devine et al., 1986; Grandin, 2010a,b; Jones, Shaw, & King, 1988; Schatzmann & Jäggin-Schmucker, 2000) making rapid neck cutting and thoracic sticking difficult. This problem can be overcome by using restrainers with belly supports through bleeding the animal in the box.

11. Halal compliant stunning methods for goats

The most common methods for stunning of goats in commercial slaughterhouses are penetrating captive bolt and electrical stunning (EFSA, 2006). However, penetrating captive bolt stunning is not approved or accepted for pre-slaughter stunning of goats for halal meat production. Head to body electrical stunning is also not accepted. Head-only electrical stunning is the only approved method for stunning of goats according to Islamic authorities. The method is carried out on individual animals. The electrodes are positioned between the eyes and the base of the ears on both sides of the head. In order to allow proper placement of electrodes, the head is restrained (EFSA, 2006). Data on goat stunning is scarce and limited to only one paper of Dayen (2001) who recommended a current of at least 1.0 A at a frequency of 50 Hz for 8 s for effective stunning of goats. On the other hand, the Malaysian Standard specifies current between 0.70 A for 2–3 s (MS 1500, 2004, 2009). Due to lack of scientific evidence, we cannot recommend the stun to neck cut time. However, like in other species, stun–neck cut time should be less than 20 s to avoid goats regaining consciousness before bleeding.

12. Halal compliant stunning methods for sheep

Sheep are predominantly stunned with head-only electrical stunners and to a smaller extent with captive bolt (FCEC, 2007). Penetrating captive bolt stunning is not halal compliant.



Source: Malaysian protocol for the halal meat and poultry productions

Fig. 2. Cattle heads examined for skull damage after non-penetrative captive bolt stunning; 260: acceptable and 261: unacceptable.

13. Non-penetrating captive bolt stunning

Concussion of the brain and unconsciousness is induced by a single blow at the frontal position of the head with a blunt non-penetrating captive bolt. The shot must be aimed at the top of the head since the front of the skull is thick (Grandin, 1994). In order to achieve an accurate stun, the animal's head should be suitably presented. The gun must also be carefully cleaned and maintained so as to achieve maximal hitting power. The induced unconsciousness may last for 17 s (EFSA, 2004a). The return of rhythmic breathing can be used as a sign of regaining consciousness. Random limb movement may be ignored; however, a limb that responds vigorously in response to a stimulus is a possible sign of return to sensibility (Grandin, 1994). Therefore, neck cutting should be rapidly carried out after stunning. Finnie, Blumbergs, Manavis, Summersides, and Davies (2000) reported that non-penetrating bolt stunning resulted in skull fracture in some lambs. If this phenomenon is scientifically verified by other studies, it will be an issue of great concern to Islamic authorities.

14. Head-only electrical stunning

Head-only electrical stunning can be carried out on individual animals within a group in a pen or individually in a restrainer but it is preferable that animals are individually restrained to avoid electric shocks that may result from wrong placement of the electrodes with this method (FCEC, 2007). To achieve an effective stun, the tongs should be applied between the eyes and the base of the ears on both sides of the head. The skin of the animal should be wetted to increase the conductivity of the electric current through the wool. Pointed electrodes should be used to create better contact with sheep's skin. Pointed electrodes (electrodes with pins) give a good grip and electrical contact as they penetrate the wool and make better contact with the skin when compared to electrodes without pins (EFSA, 2004a). Electrodes with serrated edges work best in shorn sheep and if the skin is wetted (EFSA, 2004a). It is recommended to stun with 0.5–0.9 A for 2–3 s and 0.7–1.2 A for 2–3 s for lamb and sheep respectively (MS1500, 2004, 2009). Return of normal rhythmic which occurs within 24.85–29.00 s and can be used to measure the effectiveness of stunning (Velarde et al., 2002). Head only electrical stunning is reversible and the interval between stunning and neck cutting should be limited to less than 15 s to prevent the lamb from returning to sensibility before bleeding (Grandin, 2010b, chap. 9). The study conducted by Lambooy (1982) on electrical stunning of sheep had earlier showed that throat cutting should be performed within 16 s following the stun.

15. Halal compliant stunning methods for poultry

Of all the commercially available methods for stunning poultry, only water bath electrical stunning is halal compliant. Water bath electrical stunning involves hanging conscious birds upside down on a moving metal shackle line and passing through an electrified water bath, such that the current flows through the whole body towards the shackle. During water bath electrical stunning, the depth and duration of unconsciousness depends upon the amount and frequency of currents applied. The duration between shackling and stunning depends on the live bird transport system used and the layout of the processing plant (EFSA, 2004a). This may range between 1 and 3 min in chickens and 6 min in turkeys. Turkeys can also be transported in modules that allow shackling of birds, as close as desired by the processor, to the water bath stunners.

When birds are hung upside down on moving shackles, they flap. Most of them cease wing flapping within 12 s while many subsequently resume wing flapping if they are suddenly exposed to sunlight, jolting or pre-stun electric shocks at the entrance to the water bath stunner (Gregory & Bell, 1987). There should be a sufficient delay of 12 and 20 s in chickens and turkeys, respectively between shackling and stunning to provide time for the birds to stop wing flapping (EFSA, 2004a). Wing flapping can also be minimized by lower light intensity and breast comforting plates. The incidence of pre-stun shocks can be reduced by avoiding overflowing at the entrance of the water bath stunner and fitting the stunners with an electrically isolated 'entry ramp' that slopes upwards toward the bath (EFSA, 2004a; Zivotofsky & Strous, 2012). The entry ramps should be fitted so as to facilitate swinging the birds' heads into the water bath stunner, especially in turkeys. Alternatively, shackle lines may be constructed such that they dip the heads into the water bath, for instance, shackle lines are dipped (about 19°) at the entrance and rise again at the exit of the water bath stunners (Wotton & Gregory, 1991). The application time of the stun depends on the processing line speed, in relation to the length of the water bath and the amount of current delivered to birds. Chicken should be stunned with 0.25–0.5 A for 3–5 s (MS1500, 2004, 2009). Studies conducted by Munchonieve, LePottier, and Fernandez (1999) and Gregory and Wilkins (1989) showed that turkeys can be stunned by 150 mA for 4 s. Ducks on the other hand require 130 mA for 4 s (OIE, 2008, chap. 7.5). The electrode in the water bath stunner must extend to the full length of the water bath (EFSA, 2004a). For current to pass through the brain, 99% of the birds must be positioned in the water bath (Grandin, 2010b, chap. 9). Salt can be added to fresh water to increase its conductivity (OIE, 2008, chap. 7.5; Schutt-Abraham & Wormuth, 1991). The birds must be immersed up to the base of their wings such that the heads are always held close to the electrodes in the bath, where the current density is high. Such parameters as frequency, voltage, current, wave form, resistance of the apparatus and dimensions of the water bath influence the success of the stun (Hindle, Lambooij, Reimert, Workel, & Gerritizen, 2010). In order to achieve a perfect stun, every component must be adjusted perfectly. The requirements for the acceptable use of the electrical water-bath stunning for poultry are given in Table 4.

16. Accepted stunning methods for ostriches

In recent years, the market for ostrich meat has grown due to its low fat content and thus being considered a good alternative to other meats. In many countries ostrich meat may be considered a niche product but countries like South Africa and Israel have considerable experience in slaughtering ostriches for meat and leather production (EFSA, 2006). Although mechanical stunning of ostriches can be carried out successfully using a penetrating captive bolt (Lambooij, Pieterse, Hillebrand, & Dijksterhuis, 1999), the method is not accepted by Islamic authorities. In practice, ostriches are stunned by head only electrical stunning. An average current of 500 mA (~200 V) is delivered via scissor-like stunning tongs with spiked electrodes for 3 to 6 s (Lambooij et al., 1999). However, a study by Wotton and Sparrey (2002) revealed that an electrical stunning current in excess of 400 mA at 50 Hz AC, applied to the head only, would prevent recovery in more than 90% of the ostriches, when bled within 60 s from the start of stunning. The Malaysian Standard specifies current between 0.75 A for 10 s (MS 1500, 2004, 2009). The electrodes are placed on each bird on the head between the eye and ear. The stun–neck cut interval is

Table 4
Requirements for the use of electrical water-bath stunning for poultry.
Source: Malaysian protocol for the halal meat and poultry productions.

- The time from when the bird are shackled to the time they are stunned should be limited to 60 s.
- Breast comforters from shackling to enter the water bath should be used to keep the birds calm and reduce flapping.
- The depth of the electrical water bath should be such that the head of the birds are completely immersed up to the base of their wings.
- Shackles should provide good electrical contact.
- The birds must be immersed in the water bath for at least 4 s

limited to less than 25 s (Lambooij et al., 1999). Following the stun, the birds are shackled by both legs by chains hanging from the ends of an upturned horizontal bar for subsequent bleeding.

17. Ways to improve humaneness of halal slaughtering without stunning

Ritual slaughter without prior stunning is exempt from the Humane Methods of Slaughter Act of 1958 and its revision of 1978 to protect freedom of expression of religious beliefs (College of law, 2011; Libby, 1975). In some societies, pre-slaughter stunning is not yet accepted while in some developing countries there is a general lack of stunning facilities, which calls for provision of an alternative. It is also unfortunate that for every stunning method, there will be miss-stuns (Zivotofsky & Strous, 2012), which make it necessary to have a backup system. There is a huge need for information on strategies to improve animal welfare on a practical level (Grandin, 2010b, chap. 9). Knowing that the basic causes of animal welfare problems at slaughter plants include; stressful equipment and methods, distractions that impede animal movement, lack of employee training, poor equipment maintenance and poor conditions of the animals arriving at the plant (Grandin, 1996), practical ways must be suggested to improve humaneness of halal slaughtering.

The slaughter knife should be very sharp and as long as twice the width of the animal's neck. Grandin (2010a) observed that knives that are too short and whose tips gouge into the neck would often cause violent struggling. A straight, razor-sharp knife which is twice the width of the animal's neck reduces pain (Grandin, 2004). It should be noted the knife should never be sharpened in front of the animal and an animal should not be slaughtered in front others of its own kind. The cut should be made at the first cervical vertebra. Making the neck at the first cervical vertebra instead of the second to fourth cervical vertebrae reduced the frequency of false aneurysm formation and early arrested blood flow (Gregory et al., 2012). Grandin (1994) mentioned that near immediate collapse could be induced in over 95% of cattle if the ritual slaughterer made a rapid, deep cut close to the jawbone. In order to improve animal welfare, more training programs should be organized to teach slaughter men the basic principles of humane slaughter. The animal should be slaughtered in a standing position. The American Meat Institute (AMI) Foundation's guidelines recommend that halal slaughter be performed on animals in the upright position (AMI, 2007). Restraining the animal in a comfortable, upright position is less stressful compared to shackling or hoisting (Grandin, 2010b, chap. 9). Restraint devices such as the one shown in Fig. 3 have been designed and built to hold the animal in a comfortable upright position during slaughter (Grandin, 1994; Grandin & Regenstein, 1994). Operation guidelines have been described by Grandin (1988, 1991, 1992, 1993) and Grandin and Regenstein (1994). The head should be restrained in such a manner that prevents the incision from closing back over the knife. Grandin (1994) observed that cattle and sheep struggle violently if the edges of the incision touch during the cut. After the head has been locked, chin lifters can be used to prevent movement during slaughter (Gregory, 2007). Following the cut, the head holder should be loosened slightly in order to allow the animal to relax.

Thoracic sticking as an additional procedure used after a slaughter is discouraged according to the Islamic law but since it is done after severing of the carotid artery, jugular vein, esophagus and trachea, it can be halal (Brunei State Mufti's Office, 2007). The meat of the animal involved is halal subject to four conditions; (1) a proper slaughter was done (the carotid artery, jugular vein, esophagus and trachea were cut); (2) the method is carried out after complete bleeding has taken place or 30 s after the slaughter; (3) it is confirmed that the animal died from the slaughter and the thoracic sticking procedure was merely carried out to help expedite the death; and (4) the procedure is supervised by a qualified Muslim worker (Brunei State Mufti's Office, 2007; Jamaluddin, 2007). Thoracic sticking involves

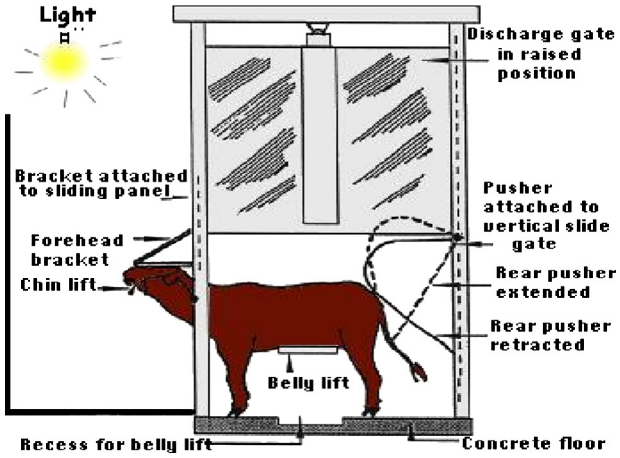


Fig. 3. A well designed upright restraint for cattle.

severing major blood vessels emerging from the heart by inserting a knife in front of the brisket or sternum (Dialrel, 2009). Sticking initiates primary bleeding and hastens the onset of irreversible insensibility of animals thus reducing pain (EFSA, 2004a; Sheridan, 2005) due to cerebral ischemia (Dialrel, 2009). Sticking severs the major vessels to the heart which includes the common brachiocephalic trunk that conveys blood from the aorta to the common carotid arteries and the subclavian arteries (Anil, Whittington, & McKinstry, 2000). Cutting the major blood vessels arising from the heart prevents occlusions and reduces arterial blood flow (Anil et al., 1995) and therefore blood loss is faster. Gregory (1985) argues that although blood can also be diverted away from the brain by cutting the major arteries in the neck, only severing the jugular veins and the vena cava would take longer to kill the animal as extensive hemorrhaging is required before arterial supply to the brain is diminished. Therefore, thoracic sticking is recommended as severance of the brachiocephalic trunk ensures rapid exsanguination and prevents blood from reaching the neck and brain resulting in cerebral ischemia. However, separate knives should be used for making incision of the skin and blood vessels in order to minimize the risk of translocation of pathogens from the skin onto the carcass or meat.

In order to maintain a high standard of animal welfare during slaughter, employees should be well trained and equipment well designed (Grandin, 2006). According to Grandin (1996), plants which have good animal welfare have managers who train and supervise their employees. Maintaining a high standard of animal welfare requires constant management attention and vigilance.

18. Conclusion

All killing methods are stressful to animals. It is therefore important that all operators involved with stunning and slaughter are competent, properly trained and have a positive attitude towards the welfare of the animals. The equipment should be maintained in good working conditions and used according to the instructions of the manufacturer(s). It is important to note that inaccurate shooting positions with a captive bolt pistol, inappropriate cartridge size, or air pressure in pneumatically operated percussion systems, inadequate current flow or poor electrode placement in electrical stunning and delayed induction of anesthesia in gas stunning will all compromise animal welfare. Better treatment of animals at slaughter improves animal welfare, which causes the animals to behave more calmly, thereby improving the occupational safety of employees and as well as reducing physical injuries to animals.

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