

Review

## Effect of halal and stunning slaughter methods on meat quality: A review

<sup>1,2\*</sup>Abd El-Rahim, I. H. A., <sup>1</sup>Mashat, B. H. and <sup>3,4</sup>Fat'hi, S. M.

<sup>1</sup>Department of Environmental and Health Research, Umm Al-Qura University,  
P.O. Box 6287, 21955 Makkah, Saudi Arabia

<sup>2</sup>Infectious Diseases, Department of Animal Medicine, Faculty of Veterinary Medicine,  
Assiut University, 71526 Assiut, Egypt

<sup>3</sup>Department of Veterinary Medicine, College of Agriculture and Veterinary Medicine,  
Qasem University, P.O. Box 6622, 51452 Buriadh, Saudi Arabia

<sup>4</sup>Department of Meat Hygiene, Faculty of Veterinary Medicine,  
Assiut University, 71526 Assiut, Egypt

### Article history

Received:

6 September 2021

Received in revised form:

25 January 2022

Accepted:

19 May 2022

### Keywords

bacterial growth,

bleeding,

halal slaughter,

meat quality,

stunning methods

### Abstract

The handling and slaughtering processes for animals have a significant effect on meat quality. Islamic (halal) slaughter and many different stunning methods are used in the meat industry worldwide. The objective of the present review was to update the current literature and practices concerning halal slaughter and stunning methods, and their effects on meat quality. The present review used inductive reasoning and comparison between halal and stunning methods for the slaughtering of farm animals. Halal slaughter involves cutting the carotid arteries, jugular veins, oesophagus, and throat without stunning. Halal slaughter facilitates the draining of blood from the animal, which is necessary to produce high-quality meat with good conservation and increased shelf life. On the other hand, most stunning slaughter hinders the bleeding process in sheep and goats. The retained blood content may act as a suitable medium for the growth and multiplication of different kinds of harmful microorganisms and make badly bled meat hard to preserve. Proper halal slaughter has several advantages regarding meat quality in comparison to stunning methods, and requires greater management attention pre-, during, and post-slaughtering to maintain good welfare and the production of high-quality meat.

### DOI

<https://doi.org/10.47836/ifrj.30.2.02>

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### Introduction

In good slaughtering, humane conditions must be present during pre-slaughter handling. The animal should not be unduly stressed and treated cruelly, carcass bruising must be minimal, and bleeding must be performed as completely as possible; furthermore, the slaughtering must be performed under safe and hygienic conditions (Roça, 2002). In addition, bad practices such as dragging, dropping, *puntilla* (death blow), hoisting, and throwing live animals before a religiously-based slaughter should be prohibited (Grandin, 2010).

The halal slaughter method consists of a horizontal cut to the throat to sever all throat blood vessels, which results in removing the blood from the

animal's body. A sharp knife and skilled slaughterer are required for proper halal slaughtering to minimise pain and suffering for the animal, as well as to accomplish the quick severing of the four blood vessels of the throat, without cutting the spinal cord (Farouk *et al.*, 2014; Imlan *et al.*, 2020). Meat produced in this way would be considered of the highest spiritual quality for Muslims. However, this halal slaughter method is critiqued by others who argue the animal should be stunned before slaughter to avoid compromising its welfare (Farouk *et al.*, 2014).

Pre-slaughter stunning is a technical process where insensibility and unconsciousness are induced in the animal to minimise the pain and suffering associated with slaughter (EFSA, 2004; Limon *et al.*,

\*Corresponding author.

Email: [ihabdelrahim@uqu.edu.sa](mailto:ihabdelrahim@uqu.edu.sa)

2010; AWI, 2020), and to enable easier and safer manipulation and handling, especially of large animals (Bergeaud-Blackler, 2007).

However, stunning impairs the bleeding process in slaughtered cattle (Bartels, 1980; Petty *et al.*, 1994). Blood undergoes putrefaction quickly due to its high protein content and high pH (7.35 - 7.45) (Mucciolo, 1985). In the case of incomplete bleeding in slaughtered bulls, the remainder of the blood stays in the muscles with a pH of about 7, thus leading to an increase in meat pH and water activity of the meat. The increase in pH and water activity facilitate the growth and multiplication of microorganisms that cause spoilage of the produced meat (Lahucky *et al.*, 1998). Additionally, stunning and other stress factors lead to disorders in the glycolysis process at rigor mortis, thus resulting in low acidity of the muscles, which favours rapid proliferation of microorganisms, and subsequently, this meat and its products spoil faster (Bender, 1992).

Worldwide, the growing demand for meat and meat products is unsustainable. This global issue cannot be solved with modern technologies alone (de Bakker and Dagevos, 2012). The technological methods of the meat industry are usually changed to meet new requirements, and sometimes may be inconsistent with basic religious norms (Abdullah *et al.*, 2019). Several modern practices for livestock management may cause stress for farm animals and affect their health, welfare, and production (Orihuela, 2021). The present review aimed to gain a better

understanding and discuss in detail, with reference to previous studies and research, the effects of halal and stunning slaughter methods on meat quality.

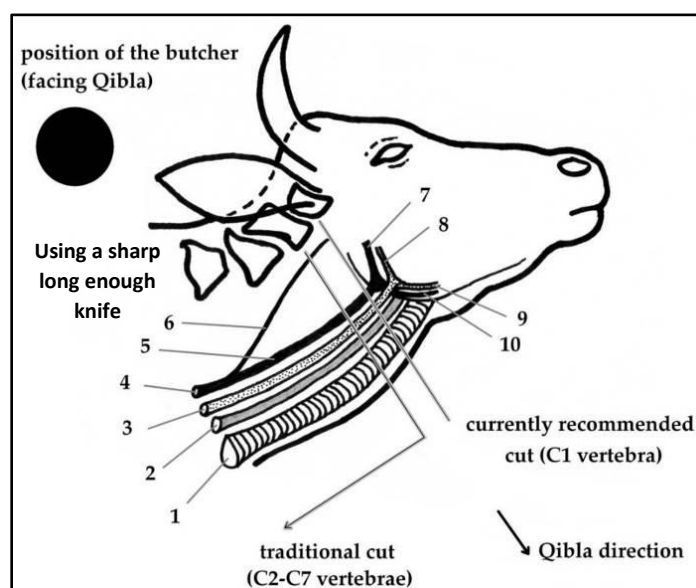
## Materials and methods

The effects of halal and stunning slaughter methods on meat quality were discussed in the present review which used inductive reasoning and a comparison between halal and stunning methods for the slaughtering of farm animals and poultry. Evidence gathered from a structured and systematic literature review and supported by existing empirical data, personal observations, and experience was also used.

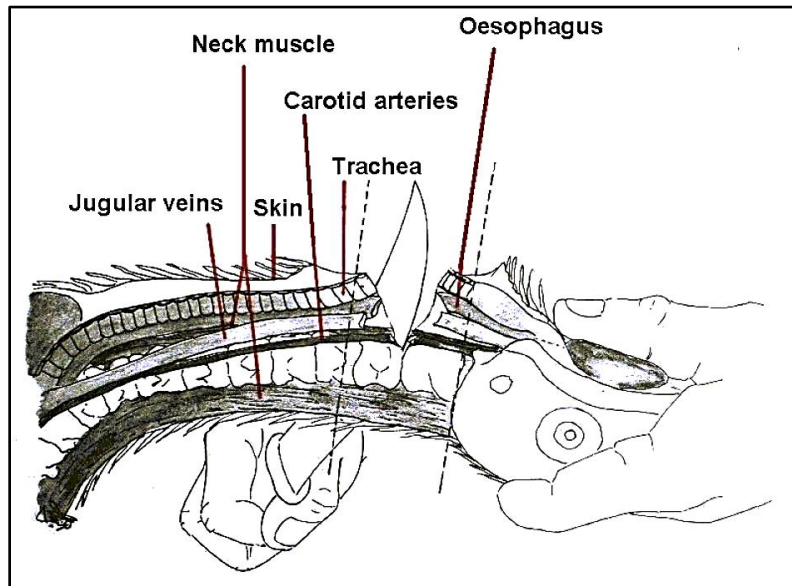
## Results

### Halal slaughter and meat quality

In halal methods, the animals/birds to be slaughtered should be halal, healthy, and not fatigued, stressed, neurotic, or excited. Pre-slaughter management includes laying the animal on its left flank. The Islamic guidelines state that while reciting the name of Allah, the slaughterer should make a quick incision on the front of the neck to cut the jugular veins, carotid arteries, oesophagus, and windpipe (Figures 1 and 2). This enables complete bleeding and a painless death (Awan and Sohaib, 2016).



**Figure 1.** Halal slaughter method in cattle (Abdullah *et al.*, 2019). 1: trachea; 2: oesophagus; 3: vena jugularis externa dextra; 4: arteria carotis communis; 5: arteria carotis externa dextra; 6: arteria carotis interna dextra; 7: arteria maxillaris; 8: vena maxillaris; 9: vena linguofacialis; and 10: truncus linguofacialis.



**Figure 2.** Halal slaughter of chicken (Malaysian Standard, 2004).

A sharp knife and skilled slaughterer are required for proper halal slaughtering to minimise pain and suffering for the animal as well as to accomplish the quick severing of the four blood vessels of the throat without cutting the spinal cord. The subsequent massive and quick bleeding induces unconsciousness in seconds (Farouk *et al.*, 2014). In halal slaughter, the animals should be in a mindful and attentive state; there is zero tolerance of animal abuse throughout the meat production supply chain (Farouk *et al.*, 2016).

Handling of animals before and during slaughter contributes significantly to meat quality (Adzitey and Huda, 2012). Post-transport resting (the lairage facilities) is important for cattle to ensure the possibility of real rest and recovery after transport (Marahrens *et al.*, 2003). In cattle, one study showed that animal stress due to long transportation led to an increase in the plasma levels of bovine heat shock protein 70 (HSPA1A) and cortisol, while it decreased levels of glucose (Chulayo *et al.*, 2016). The halal slaughter method includes providing the animal rest and full access to water and feed before slaughtering (Farouk *et al.*, 2014).

Bleeding efficiency is an important requirement of halal slaughter to obtain good quality meat (Warriss, 1977). In rabbits, the post-mortem changes, which take place in the muscles, have a large effect on meat safety and hygiene. In halal slaughter, maximum drainage of blood flow occurs and removes the microorganisms and wastes, thus improving the meat's quality, taste, healthiness, and shelf life (Nakyinsige *et al.*, 2014). Bovine slaughtering

without stunning has a positive effect on bleeding efficiency. One study showed that cattle slaughtered without stunning had less residual haemoglobin retained in the muscles, and better bleeding efficiency than pneumatic-powered stunned cattle (Roça *et al.*, 2001). Another study showed that the bleed-out was not adversely affected by captive bolt stunning, nor improved by a neck cut without stunning in cattle (Anil *et al.*, 2006). In poultry, the blood volume lost from non-halal slaughtered chickens was significantly ( $p < 0.05$ ) lower than from the halal slaughtered birds (Hakim *et al.*, 2020).

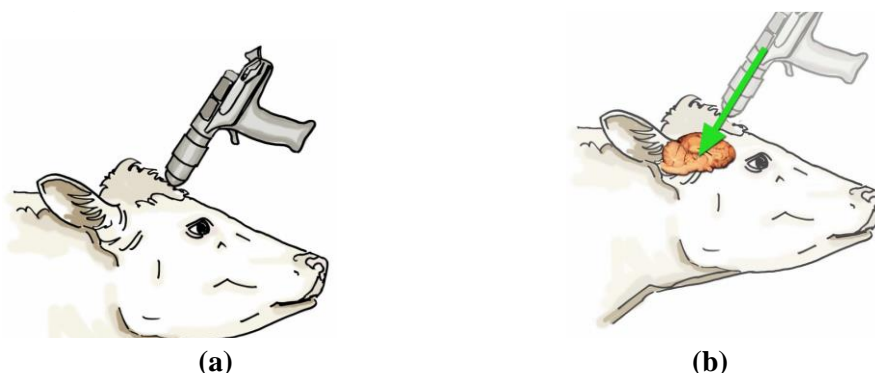
#### *Stunning slaughter methods and meat quality*

The main objective of stunning is to produce an unconscious state that should last until the end of the bleeding process (Velarde *et al.*, 2014). In Europe, the law requires that all poultry and animals should be stunned pre-slaughter to render them unconscious (Sante *et al.*, 2000).

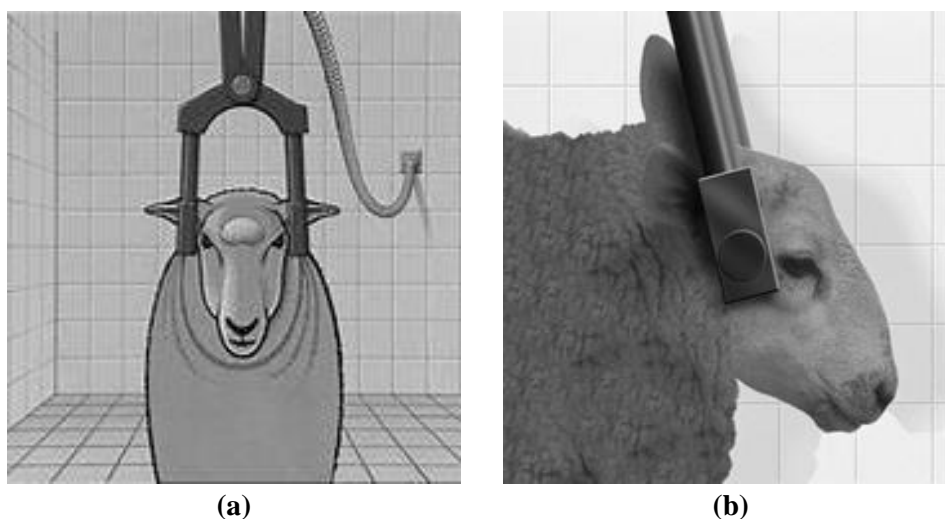
There are several types of stunning used for different animals and bird species. These types, based on the method or instrument, are cash knockers, firearm-gunshot, cartridge-fired captive bolt stunners, pneumatic-powered stunners, pneumatic-powered air injection stunners, chemical processes, and electronarcosis (Roça, 2002). The stunning methods are different based on the animal species. For cattle, sheep and goats, the stunning methods can be classified in two groups: mechanical and electrical (Figures 3 and 4). The mechanical methods are penetrative and non-penetrative captive bolt stunning as well as stunning using firearms with free

projectiles. In addition to stunning using percussive blow to the head for sheep and goats. Electrical methods include head-only and head-to-body stunning (EFSA AHAW Panel *et al.*, 2020b; 2021).

However, most countries have banned air injection stunners to prevent brain material from being forced into the meat.



**Figure 3.** Captive bolt stunning in cattle; (a) non-penetrating and (b) penetrating (Anil, 2012; Al-Teinaz *et al.*, 2020).



**Figure 4.** Head-only electrical stunning in sheep. Electrode position for sheep; (a) front view and (b) side view (HSA, 2016).

Electrical stunning, controlled atmospheres, and mechanical stunning are relevant for poultry (EFSA AHAW Panel *et al.*, 2019). The equipment, procedures, advantages and disadvantages, and welfare aspects of controlled atmosphere stunning (CAS) and low atmospheric pressure stunning (LAPS) for poultry were described by Grandin (2020).

A pneumatic stunner or a captive bolt pistol are used in most bovine slaughterhouses, while electric stunning is used in most ovine and caprine slaughterhouses. The electric water trough is usually used for poultry. In poultry slaughterhouses, an electric water trough is unacceptable from both

animal welfare and halal viewpoints (Fuseini *et al.*, 2018). During gas stunning in rabbits, too low a concentration of carbon dioxide and/or too-short exposure time, lead to severe pain, fear, and respiratory distress. Inhalation of highly concentrated carbon dioxide alone or mixed with other gases such as nitrogen or argon may kill animals (EFSA AHAW Panel *et al.*, 2020a).

In ruminants and poultry, a properly applied high frequency electrical stunning is reversible, and enhances meat quality. However, rapid bleeding is necessary to maintain animal welfare. Low frequency electrical stunning reduces bleeding efficiency, and negatively affects the quality of meat (Sabow *et al.*,

2017). Head-only stunning in animals, and water-bath stunning in birds can be considered acceptable methods for halal slaughter by some Muslim scholars. However, stunning should not induce cardiac arrest, cerebral damage, physical disability, or death (Nakyinsige *et al.*, 2013). Meanwhile, low frequency head-to-back electrical stunning of goats is not acceptable for halal slaughtering as it causes cardiac arrest (Sabow *et al.*, 2019).

For stunning slaughter of cattle, the percentage of circulating adrenocorticotrophic hormone (ACTH) was very high, thus indicating the presence of a physiological stress response and severe stress (Zulkifli *et al.*, 2014). Therefore, proper stunning of cattle is necessary to avoid animal welfare risks at slaughterhouses (Wagner *et al.*, 2019). In bulls, animal welfare will be compromised in the form of severe pain and distress in the case of incomplete stunning (Gibson *et al.*, 2019). In the case of microwave stunning systems, cattle that receive lower energy applications can return to consciousness (Small *et al.*, 2019). Therefore, microwave stunning systems are not used commercially.

Stunning methods can have adverse effects on meat quality and public health, in addition to the possibility of mis-stunning (Anil, 2012; Farouk *et al.*, 2014). The specific adverse effects of stunning in sheep and cattle can be summarised as follows: (a) bruising in cattle due to heavy falls after stunning; (b) blood splash (petechial haemorrhages) and bruising in both cattle and sheep caused by electrical stunning; and (c) pelt-burn in sheep during head-to-back stunning due to contact of the rear electrode on the back of neck (Anil, 2012).

In large animals, excessive convulsions after electrical stunning can have adverse effects on pH and meat quality (Anil, 2012). In the United Kingdom, a survey of halal certifying bodies (HCBs) revealed that none of the surveyed HCBs accepted penetrative captive bolt stunning for halal meat production because it may lead to the death of the animals before complete bleeding (Fuseini *et al.*, 2020).

The potential zoonotic risk of transmissible spongiform encephalopathy (TSE) during stunning was also reported. Embolism of brain tissues was detected in the venous blood of captive-bolt-stunned cattle. Since the heartbeats continue for several minutes between the stunning and the end of exsanguination, some of the central nervous material

may circulate in the veins exiting the brain and reach other organs and tissues. Such prion-contaminated meat could be a source of infection for consumers (Anil and Harbour, 2001; Anil *et al.*, 2002; Coore *et al.*, 2004; 2005). This may also occur due to contamination of the meat with spinal cord tissue during splitting of the carcasses in both halal and stunning slaughtering (Helps *et al.*, 2002; Bowling *et al.*, 2007). Table 1 summarises the differences between the halal and stunning slaughter methods and their effect on meat quality.

## Discussion

There are many procedures for animal slaughter worldwide. One of them is the religious (halal) slaughtering method practiced by Muslims (Farouk, 2013). The present review summarises the halal slaughter method without stunning, by the horizontal cut of the throat (jugular veins, carotid arteries, oesophagus, and trachea) using a sharp and long enough knife, without severing the spinal cord, while the animal is alive, rested, and calm.

Halal slaughtering should be performed by a prompt cut in one uniform continuous movement using a sharp and long knife at the correct site of the neck without any interruption, uncertainty, or unnecessary delay (Helmut, 2010). For proper halal slaughtering, the religious-recommended management including resting, proper handling of the animal, mention of the name of God "Allah", using sharp and long enough knife, severing all neck blood vessels in one quick horizontal incision, and keeping the head connected to the body during bleeding should be applied, and the slaughterer should be well-trained.

In halal slaughter, the live animal should be handled carefully, should have free access to feed and water, and should be allowed to rest before slaughtering. A suitable pen would keep the animals in a natural position, and prevent their excessive movement just before slaughtering; the slaughterer should use a sharp knife, and finally, the neck cut should be at the first cervical vertebra, according to Barrasso *et al.* (2020). These arrangements will produce high-quality meat. The Office International des Epizooties (OIE), now the World Organisation for Animal Health (WOAH), slaughter standards stated that stressful methods of restraint before animal slaughter should not be used (OIE, 2021). Grandin

**Table 1.** Differences between halal and stunning slaughter methods, and their effect on meat quality.

Comparison	Halal slaughtering	Stunning slaughtering
Definition	While reciting the name of Allah, the skilled Muslim slaughterer makes a quick horizontal incision on the front of the neck using a sharp long enough knife to cut the jugular veins, carotid arteries, oesophagus, and trachea without cutting the spinal cord (Farouk <i>et al.</i> , 2014; Awan and Sohaib, 2016; Imlan <i>et al.</i> , 2020).	Pre-slaughter stunning is a technical process to induce insensibility and unconsciousness in an animal to minimise the pain and suffering associated with slaughter (EFSA, 2004; Limon <i>et al.</i> , 2010; AWI, 2020).
Bleeding	The bleeding is complete, because the severing of all throat blood vessels of the alive and conscious animal results in removing the blood from the animal's body (Helmut, 2010; Farouk <i>et al.</i> , 2014; Awan and Sohaib, 2016)	The bleeding is inefficient, because stunning impairs the bleeding process (Bartels, 1980, Petty <i>et al.</i> , 1994).
Microbial load*	In halal slaughter, removal of all blood from the carcasses removes the microorganisms and wastes, thus improving the meat's quality, taste, health, and shelf life (Aghwan <i>et al.</i> , 2016).	Inefficient bleeding (blood remaining in the musculature with a pH of about 7.35 to 7.45) leads to an increase in meat pH and a rise in meat water activity, which is ideal media for microbial growth and making badly bled meat hard to preserve (Mucciolo, 1985; Roça <i>et al.</i> , 2001). Additionally, it was indicated that the low frequency head-only electrical stunning in goats led to low bleed-out with subsequent low microbiological quality of meat during aging (Sabow <i>et al.</i> , 2016b).
Glycolysis		Stunning irritates the living animals, thus leading to disorders in the glycolysis process at rigor mortis, resulting in low acidity of the muscles, which favours rapid proliferation of microorganisms (Bender, 1992).

\*The microbial information only applies to lamb, sheep, and goats.

(2017) mentioned that highly stressful methods of restraint and abusive handling practices before slaughter may cause more suffering than the actual slaughter itself. Stressful restraint methods such as shackling and hoisting, or shackling and dragging should be prohibited. Sabow *et al.* (2016a) reported electroencephalographic (EEG) activities with the presence of post-slaughter noxious sensory input in goats slaughtered without stunning, and this may be due to pain in slaughtered goats. However, they did

not describe either the knife or the restraint methods used for the slaughtering of these goats.

Complete cutting and separation of the head before the death of the slaughtered animal should be avoided in proper halal slaughter. This is necessary to complete the bleeding process, *i.e.*, removal of all blood from the carcass. Helmut (2010) stated that the horizontal cut of the ventral aspect of the neck should not reach the spine. Additionally, the head of the slaughtered animal should not be separated from its

body during the slaughtering and bleeding processes.

Improper pre-slaughter handling compromises an animal's welfare especially in developing countries (Adzitey, 2011). Boyle and O'Driscoll (2011) stated that animal welfare is an important character of the meat quality. There is a growing realisation of the relationship between animal welfare and food safety. Therefore, the present review suggests that more education and training are needed to conduct halal slaughter properly without compromising animal welfare. Firstly, the live animals should be handled gently and carefully before and during slaughtering. The live animal should be rested and in a calm state before slaughtering. Slaughtering of an animal in front of others should be avoided (Lahucky *et al.*, 1998). A special long enough sharp knife and skilled slaughterer are required (Grandin and Regenstein, 1994; Farouk *et al.*, 2014). While the slaughterer recites the name of Allah, they make a quick horizontal incision on the front of the neck to accomplish the quick severing of the four blood vessels of the throat, oesophagus, and windpipe without injury of the spinal cord (Farouk *et al.*, 2014; Awan and Sohaib, 2016). Zero tolerance of animal abuse should be present along the meat production supply chain (Farouk *et al.*, 2016).

Generally, the ethical responsibilities of animal slaughter for meat production should be balanced with science and societal values to be sure that the animals are humanely treated (Edwards-Callaway and Calvo-Lorenzo, 2020). Humane slaughter means that an animal experiences minimal distress and pain during slaughtering. Commonly, stunning is used to induce insensibility; however, it is considered unsatisfactory by some religious groups (Rault *et al.*, 2014). It has been reported that electrical stunning in cattle causes epileptiform activity in the brain, and induces instantaneous unconsciousness with atrial or ventricular fibrillation (Lambooy and Spanjaard, 1982; Wotton *et al.*, 2000). In electrical stunning, the electrical energy travels through the body, thus resulting in severe muscle cramps and paralysis of both respiratory muscles and vocal cords, which induces stress and pain for the paralysed animal (Yardimci, 2019). Furthermore, a significant increase in the level of adrenaline and corticosterone was detected in electrically stunned broilers (Zulkifli *et al.*, 2019).

Stunning of cattle using the non-penetrating captive bolt gun usually needed reshooting to ensure the depth of concussion, and to avoid inducing severe

pain during bleeding (Neves *et al.*, 2016). The penetrating captive bolt was more effective than a non-penetrating captive bolt in rendering stunned bulls unconscious (Gibson *et al.*, 2019).

Khalid (2011) stated that many factors affect the bleeding process in lambs, such as the severed vessels, patency of the sticking wound, muscular contractility, cardiac arrest, the vertical or horizontal orientation of the carcass, time for bleeding, and dressing procedures. Nakyinsige *et al.* (2014) found that halal slaughter of rabbits resulted in significantly higher blood loss than gas-stun-killing, and concluded that the religious slaughtering method could be successfully used as an alternative to stunning methods to produce meat of better quality. Farouk *et al.* (2014) stated that several meat quality problems such as carcass damage, muscular haemorrhages, broken bones, reduced ageing potential, poor colour stability, and increased drip loss are associated with pre-slaughter stunning methods, while these problems are rarely found in the meat of non-stunned animals. Aghwan *et al.* (2016) found that the complete bleeding process, which occurs in proper halal slaughtering, maintains meat quality. Some other studies (Velarde *et al.*, 2003; Khalid *et al.*, 2015) showed no significant difference in blood loss during exsanguination between non-stunned and electric head-only stunning in sheep. Gregory *et al.* (2010) stated that in the case of improper halal slaughtering of cattle, a slow knife stroke can stretch the arteries and induce occlusion, thus leading to delayed onset of unconsciousness. The swelling of the cephalic ends of the carotid arteries causes the failure of the slaughtered non-stunned cattle to collapse within 60 seconds. Therefore, the present review concludes that the application of the proper method of halal slaughter is crucial.

Perishable meat is a good medium for the proliferation and growth of different kinds of harmful microorganisms. Therefore, it is important to control the proliferation of spoilage microorganisms to maintain the flavour, texture, and nutritional value of the produced meat as well as to increase its shelf life (Dave and Ghaly, 2011). Therefore, proper halal slaughter aims to increase the flow of free or liquid blood as much as possible from the animal's body after slaughtering, because free blood is a suitable enrichment media for microbial growth. Severing of throat blood vessels and keeping the head connected to the animal body (without injury of the spinal cord) assist in complete bleeding. This maintains the

connection between the brain and the animal's body through the spinal cord to send hormonal alerts and nerve signals, which are required to remove all the liquid blood from carcasses. In proper halal slaughter, the head can be separated only after confirming that the animal is completely dead. In chickens, Davis (1996) found that cutting of the jugular veins and carotid arteries without head separation shorten the time of death, while head decapitation increases time of death as it disrupts the nervous system inducing suffocation and asphyxia. Zaman *et al.* (2012) detected a difference in the total protein profile in the muscles of chickens slaughtered by two methods with a sharp knife. In the first group, the spinal cord was intact, and the head kept connected until the bird died. In the second one, the neck was completely cut off. It was found that the meat pH was 5.0, and the molecular weight was 116 kDa in the skeletal muscle of the second group only.

Five to seven days post-mortem, Nakynsige *et al.* (2014) observed that the bacterial counts were affected by the method used for slaughtering of rabbits, where the gas stun-killing method induced significantly higher bacterial growth than the halal slaughter method. It was found that halal slaughter led to lowering of the various microbial loads in broiler chicken meat, while in non-halal slaughter, retained blood in the muscles stimulated bacterial multiplication due to its favourable pH and high nutritive value (Addeen *et al.*, 2014). Furthermore, the slaughter method of poultry significantly affected the meat quality and shelf life. Non-halal slaughtered poultry contained more residual blood in the meat, which led to an increase in microbial counts with subsequent shortened shelf life (Hafiz *et al.*, 2015; Hakim *et al.*, 2020).

Poor pre-slaughter handling of animals (*e.g.*, stunning) has adverse effects on the carcass and meat quality. It can cause animal death, reduction in live weight, carcass damage, dark firm dry and pale soft exudative meats as well as microbial contamination (Adzitey, 2011), which may lead to bacterial foodborne diseases for consumers (Abdul-Mutalib, *et al.*, 2015). Slaughter methods affect the levels of plasmatic cortisol in calves, which influences the correct acidification of meat (Ceci *et al.*, 2017). In cattle, it was found that pre-slaughter handling affected muscle glycogen concentration (Önenç and Kaya, 2004). At rigor mortis, the muscle glycogen is converted into lactic acid, thus leading to a decrease in pH from the initial values of pH 6.8 - 7.3 to about

5.4 - 5.8. Stressful handling before slaughter irritates the living animals, thus resulting in secretion of a high amount of the adrenalin, which leads to a reduction in muscle glycogen. Therefore, during rigor mortis, the glycolysis process does not occur correctly, and the formed lactic acid is not enough to decrease the meat pH to 5.4 - 5.8. Then, the pH of the meat will be more than the natural and normal status (more than 5.4 - 5.8), thus facilitating the growth and multiplication of the spoilage microorganisms, and making the meat perishable. In lambs, Linares *et al.* (2007) concluded that stunning methods could accelerate meat aging and cause changes in colour and water losses as well as other quality parameters. In contrast, the normal ultimate pH values of properly halal slaughtered meat (pH 5.4 - 5.8) provide unfavourable media for the multiplication of microorganisms, thus producing bright red and good-tasting meat as well as increasing shelf life.

Some stunning methods such as the captive-bolt-stunning of cattle and sheep may result in contamination of the meat with nervous tissue prion-infected materials (Anil and Harbour, 2001; Anil *et al.*, 2002; Coore *et al.*, 2004; 2005). It is a concern for public health that the application of some kinds of stunning before slaughtering of prion-infected cattle and sheep may lead to haematogenous contamination of muscles and tissues with the infected central nervous system (CNS) material. Consequently, for consumers, the contaminated meat may act as a source of infection of prion zoonotic incurable diseases. Contamination of the carcasses with the nervous tissue may occur during both halal and stunning slaughtering through the splitting saw, which can disseminate spinal cord tissue over the carcass (Helps *et al.*, 2002; Bowling *et al.*, 2007).

The use of irreversible stunning in red meat species and water bath stunning of poultry may increase the risk of death of animals and birds. Irreversible stunning methods of large animal species may cause cardiac fibrillation or severe cerebral damage in the case of mechanical stunning leading to animal death before slaughter, particularly when there is a delay between stunning and slaughtering. In addition, water bath electric stunning for poultry can lead to cardiac arrest and cause death before slaughter, especially in low-resistant birds that receive too much current (Fuseini *et al.*, 2016). The meat of dead animals or birds due to stunning until death is haram (unlawful) for Muslims, and may pose a serious risk to human health if consumed.



## Conclusion

The present review concludes that proper halal slaughter has many advantages in term of meat quality in comparison to stunning slaughter methods. Proper halal slaughtering induces efficient bleeding and subsequent production of high-quality meat; stunning methods hinder the bleeding process and make meat a suitable medium for bacterial growth. In addition, animals and poultry that die during stunning are unlawful (prohibited; haram or non-halal) for Muslims. Proper halal slaughter requires greater management attention pre-, during, and post-, slaughtering to maintain good animal welfare and high-quality meat production.

## Acknowledgement

The authors acknowledge the Deanship of Scientific Research at Umm Al-Qura University for financially supporting the present review (grant no.: 22UQU4320609DSR01).

## References

- Abdullah, F. A. A., Borilova, G. and Steinhäuserova, I. 2019. Halal criteria versus conventional slaughter technology. *Animals* 9(8): 530-542.
- Abdul-Mutalib, N. A., Syafinaz, A. N., Sakai, K. and Shirai, Y. 2015. An overview of foodborne illness and food safety in Malaysia. *International Food Research Journal* 22(3): 896-901.
- Addeen, A., Benjakul, S., Wattanachant, S. and Moqsood, S. 2014. Effect of Islamic slaughtering on chemical compositions and post-mortem quality changes of broiler chicken meat. *International Food Research Journal* 21(3): 897-907.
- Adzitey, F. 2011. Effect of pre-slaughter animal handling on carcass and meat quality. *International Food Research Journal* 18: 485-491.
- Adzitey, F. and Huda, N. 2012. Effects of post-slaughter carcass handling on meat quality. *Pakistan Veterinary Journal* 32: 161-164.
- Aghwan, Z. A., Bello, A. U., Abubakar, A. A., Imlan, J. C. and Sazili, A. Q. 2016. Efficient halal bleeding, animal handling, and welfare: A holistic approach for meat quality. *Meat Science* 121: 420-428.
- Al-Teinaz, Y. R., Spear, S. and Abd El-Rahim, I. H. 2020. *The halal food handbook*. Hoboken: Wiley.
- Anil, M. H. 2012. Effects of slaughter method on carcass and meat characteristics in the meat of cattle and sheep. Retrieved from website: [https://projectblue.blob.core.windows.net/media/Default/Research%20Papers/Beef%20&%20Lamb/slaughter\\_and\\_meat\\_quality\\_feb\\_2012-final-report.pdf](https://projectblue.blob.core.windows.net/media/Default/Research%20Papers/Beef%20&%20Lamb/slaughter_and_meat_quality_feb_2012-final-report.pdf)
- Anil, M. H. and Harbour, D. 2001. Current stunning and slaughter methods in cattle and sheep: Potential for carcass contamination with central nervous tissue and microorganisms. *Fleischwirtschaft International* 3: 26-27.
- Anil, M. H., Love, S., Helps, C. R. and Harbour, D. 2002. Potential for carcass contamination with brain tissue following stunning and slaughter in cattle and sheep. *Food Control* 13: 431-436.
- Anil, M. H., Yesildere, T., Aksu, H., Matur, E., McKinstry, J. L., Weaver, H. R., ... and Mason, C. 2006. Comparison of halal slaughter with captive bolt stunning and neck cutting in cattle: Exsanguination and quality parameters. *Animal Welfare* 15: 325-330.
- Animal Welfare Institute (AWI). 2020. Update on humane slaughter enforcement. Retrieved from AWI website: <https://awionline.org/awi-quarterly/summer-2020/awi-releases-latest-update-humane-slaughter-enforcement>
- Awan, J. A. and Sohaib, M. 2016. Halal and humane slaughter: Comparison between Islamic teachings and modern methods. *Pakistan Journal of Food Science* 26: 234-240.
- Barrasso, R., Bonerba, E., Ceci, E., Roma, R., Alò, A., Mottola, A., ... and Bozzo, G. 2020. Evaluation of the animal welfare during religious slaughtering. *Italian Journal of Food Safety* 9(1): 8387.
- Bartels, H. 1980. *Veterinary inspection of meat*. Spain: Editorial Acribia.
- Bender, A. 1992. Meat quality. In Bender, A. (ed). *Meat and Meat Products in Human Nutrition in Developing Countries*. Rome: Food and Agriculture Organization (FAO).
- Bergeaud-Blackler, F. 2007. New challenges for Islamic ritual slaughter: A European perspective. *Journal of Ethnic and Migration Studies* 33(6): 965-980.
- Bowling, M. R., Yemm, R. S., Belk, K. E., Sofos, J. N., Smith, G. C. and Scanga, J. A. 2007. An

- evaluation of central nervous system cross-contamination due to carcass splitting in commercial beef packing plants. *Journal of Food Protection* 71(1): 83-92.
- Boyle, L. A. and O'Driscoll, K. 2011. Animal welfare: An essential component in food safety and quality. In Hoorfar, J., Jordan, K., Butler, F. and Prugger, R. (eds). *Food Chain Integrity*, p. 169-186. United Kingdom: Woodhead Publishing.
- Ceci, E., Marchetti, P., Samoilis, G., Roma, R., Barrasso, R., Tantillo, G. and Bozzo, G. 2017. Determination of plasmatic cortisol for evaluation of animal welfare during slaughter. *Italian Journal of Food Safety* 6(3): 34-66.
- Chulayo, A. Y., Bradley, G. and Muchenje, V. 2016. Effects of transport distance, lairage time and stunning efficiency on cortisol, glucose, HSPA1A and how they relate with meat quality in cattle. *Meat Science* 117: 89-96.
- Coore, R. R., Love, S., McKinstry, J. L., Weaver, H. R., Phillips, A., Hillman, T., ... and Anil, M. H. 2005. Brain tissue fragments in jugular-vein blood of cattle stunned by use of penetrating or non-penetrating captive bolt guns. *Journal of Food Protection* 68(4): 882-884.
- Coore, R. R., Love, S., McKinstry, J. L., Weaver, H. R., Phillips, A., Hillman, T., ... and Anil, M. H. 2004. Dissemination of brain emboli following captive bolt stunning of sheep: Capacity for entry into the systemic arterial system. *Journal of Food Protection* 67(5): 1050-1052.
- Dave, D. and Ghaly, A. E. 2011. Meat spoilage mechanisms and preservation techniques: A critical review. *American Journal of Agricultural and Biological Sciences* 6(4): 486-510.
- Davis, K. 1996. *Prisoned chickens, poisoned eggs: An inside look at the modern poultry industry*. United States: Book Publishing Company.
- de Bakker, E. and Dagevos, H. 2012. Reducing meat consumption in today's consumer society: Questioning the citizen-consumer gap. *Journal of Agricultural and Environmental Ethics* 25: 877-894.
- Edwards-Callaway, L. N. and Calvo-Lorenzo, M. S. 2020. Animal welfare in the U.S. slaughter industry—A focus on fed cattle. *Journal of Animal Science* 98(4): 1-21.
- EFSA AHAW Panel (EFSA Panel on Animal Health and Animal Welfare), Nielsen, S. S., Alvarez, J., Bicout, D. J., Calistri, P., Depner, K., ... and Michel, V. 2019. Slaughter of animals: Poultry. *EFSA Journal* 17: 5849.
- EFSA AHAW Panel (EFSA Panel on Animal Health and Animal Welfare), Saxmose Nielsen, S., Alvarez, J., Bicout, D. J., Calistri, P., Depner, K., ... and Spooler, H. 2020a. Scientific opinion on stunning methods and slaughter of rabbits for human consumption. *EFSA Journal* 18: 5927.
- EFSA AHAW Panel (EFSA Panel on Animal Health and Welfare), Nielsen, S. S., Alvarez, J., Bicout, D. J., Calistri, P., Depner, K., ... and Winckler, C. 2020b. Scientific Opinion on the welfare of cattle at slaughter. *EFSA Journal* 18: 6275.
- EFSA AHAW Panel (EFSA Panel on Animal Health and Welfare), Nielsen, S. S., Alvarez, J., Bicout, D. J., Calistri, P., Canali, E., ... and Michel, V. 2021. Scientific opinion on the welfare of sheep and goats at slaughter. *EFSA Journal* 19: 6882.
- European Food Safety Authority (EFSA). 2004. AHAW 04-027 - Welfare aspects of animal stunning and killing methods. Italy: EFSA.
- Farouk, M. M. 2013. Advances in the industrial production of halal and kosher red meat. *Meat Science* 95: 805-820.
- Farouk, M. M., Al-Mazeedi, H. M., Sabow, A. B., Bekhit, A. E. D., Adeyemi, K. D., Sazili, A. Q. and Ghani, A. 2014. Halal and kosher slaughter methods and meat quality: A review. *Meat Science* 98: 505-519.
- Farouk, M. M., Pufpaff, K. M. and Amir, M. 2016. Industrial halal meat production and animal welfare: A review. *Meat Science* 120: 60-70.
- Fuseini, A., Hadley, P. and Knowles, T. 2020. Halal food marketing: An evaluation of UK halal standards. *Journal of Islamic Marketing* 12(5): 977-991.
- Fuseini, A., Knowles, T. G., Hadley, P. J. and Wotton, S. B. 2016. Halal stunning and slaughter: Criteria for the assessment of dead animals. *Meat Science* 119: 132-137.
- Fuseini, A., Teye, M., Wotton, S. B., Lines, J. A. and Knowles, T. G. 2018. Electrical water bath stunning for poultry meat production: Animal welfare issues and compatibility with the halal rules. *CAB Reviews - Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* 13(16): 1-7.

- Gibson, T. J., Oliveira, S. E. O., Costa, F. A. D. and Gregory, N. G. 2019. Electroencephalographic assessment of pneumatically powered penetrating and non-penetrating captive-bolt stunning of bulls. *Meat Science* 151: 54-59.
- Grandin, T. 2010. Auditing animal welfare at slaughter plants. *Meat Science* 86(1): 56-65.
- Grandin, T. 2017. Discussion of research that shows that kosher or halal slaughter without stunning causes pain. Retrieved from Grandin website: <https://www.grandin.com/ritual/slaughter.without.stunning.causes.pain.html>
- Grandin, T. 2020. Stunning poultry with controlled atmosphere systems. In Grandin, T. and Cockram, M. (eds). *The Slaughter of Farmed Animals - Practical Ways of Enhancing Animal Welfare*. United Kingdom: CABI International.
- Grandin, T. and Regenstein, J. 1994. Religious slaughter and animal welfare: A discussion for meat scientists. *Meat Focus International* 3: 115-123.
- Gregory, N. G., Fielding, H. R., Von Wenzlawowicz, M. and Von Holleben, K. 2010. Time to collapse following slaughter without stunning in cattle. *Meat Science* 85: 66-69.
- Hafiz, A., Hassan, Z. and Abdul Manap, M. N. 2015. Effect of slaughtering methods on meat quality indicators, chemical changes and microbiological quality of broiler chicken meat during refrigerated storage. *Journal of Agriculture and Veterinary Science* 8(9): 12-17.
- Hakim, L. I., Isa, N. M. M., Tahir, S. M. and Ibitoye, E. B. 2020. Effect of halal and non-halal slaughtering methods on bacterial contamination of poultry meat. *Sains Malaysiana* 49(8): 1947-1950.
- Helmut, P. 2010. Review of stunning and halal slaughter. Australia: Meat and Livestock Australia.
- Helps, C. R., Hindell, P., Hillman, T. J., Fisher, A. V., Anil, H., Knight, A. C., ... and Harbour, D. A. 2002. Contamination of beef carcasses by spinal cord tissue during splitting. *Food Control* 13(6-7): 417-423.
- Humane Slaughter Association (HSA). 2016. Head-only stunning. Retrieved from HSA website: <https://www.hsa.org.uk/electrical-stunning-of-red-meat-animals-equipment/head-only>
- Imlan, J. C., Kaka, U., Goh, Y. M., Idrus, Z., Awad, E. A., Abubakar, A. A., ... and Sazili, A. Q. 2020. Effects of slaughter knife sharpness on blood biochemical and electroencephalogram changes in cattle. *Animals* 10(4): 579.
- Khalid, R. 2011. The bleeding of slaughtered lambs for the purposes of halal slaughter. United Kingdom: University of Bristol, MSc thesis.
- Khalid, R., Knowles, T. G. and Wotton, S. B. 2015. A comparison of blood loss during the halal slaughter of lambs following traditional religious slaughter without stunning, electric head-only stunning and post-cut electric head-only stunning. *Meat Science* 110: 15-23.
- Lahucky, R., Palanska, O., Mojto, J., Zaujec, K. and Huba, J. 1998. Effect of preslaughter handling on muscle glycogen level and selected meat quality traits in beef. *Meat Science* 50(3): 389-393.
- Lambooy, E. and Spanjaard, W. 1982. Electrical stunning in veal calves. *Meat Science* 6(1): 15-25.
- Limon, G., Guitian, J. and Gregory, N. G. 2010. An evaluation of the humaneness of puntilla in cattle. *Meat Science* 84(3): 352-355.
- Linares, M. B., Bornez, R. and Vergara, H. 2007. Effect of different stunning systems on meat quality of light lamb. *Meat Science* 76: 675-681.
- Malaysian Standard. 2004. Halal food - Production, preparation, handling and storage: General guidelines, First revision. Malaysia: Department of Standards.
- Marahrens, M., von Richtofen, I., Schmeidduch, S. and Hartung, J. 2003. Special problems of long-distance road transport of cattle. *Deutsche Tierärztliche Wochenschrift* 110: 120-125.
- Mucciolo, P. C. 1985. Killing and industrialization establishments. São Paulo: Ícone.
- Nakyinsige, K., Che Man, Y. B., Aghwan, Z. A., Zulkifli, I., Goh, Y. M., Abu Bakar, F., ... and Sazili, A. Q. 2013. Stunning and animal welfare from Islamic and scientific perspectives. *Meat Science* 95(2): 352-361.
- Nakyinsige, K., Fatimah, A. B., Aghwan, Z. A., Zulkifli, I., Goh, Y. M. and Sazili, A. Q. 2014. Bleeding efficiency and meat oxidative stability and microbiological quality of New Zealand white rabbits subjected to halal slaughter without stunning and gas stun-

- killing. *Asian-Australasian Journal of Animal Sciences* 27: 406-413.
- Neves, J. E. G., Paranhos da Costa, M. J. R., Roça, R. O. and Gregory, N. G. 2016. A note comparing the welfare of Zebu cattle following three stunning-slaughter methods. *Meat Science* 117: 41-43.
- Önenç, A. and Kaya, A. 2004. The effects of electrical stunning and percussive captive bolt stunning on meat quality of cattle processed by Turkish slaughter procedures. *Meat Science* 66(4): 809-815.
- Orihuela, A. 2021. Management of livestock behavior to improve welfare and production. *Animal* 15(1): 100290.
- Petty, D. B., Hattingh, J., Ganhao, M. F. and Bezuidenhout, L. 1994. Factors which affect blood variables of slaughtered cattle. *Journal of South Africa Veterinary Association* 65: 41-45
- Rault, J. L., Hemsworth, P., Cakebread, P., Mellor, D. and Johnson, C. 2014. Evaluation of microwave energy as a humane stunning technique based on electroencephalography (EEG) of anaesthetised cattle. *Animal Welfare* 23: 391-400.
- Roça, R. O. 2002. Humane slaughter of bovine. In *First Virtual Global Conference on Organic Beef Cattle Production*. United States: Pennsylvania State University.
- Roça, R. O., Padovani, C. R., Filipi, M. C., Schwach, E., Uemi, A., Shinkai, R. T. and Biondi, G. F. 2001. Effects of slaughter methods on efficiency. *Food Science and Technology* 21(2): 244-248.
- Sabow, A. B., Zulkifli, I., Goh, Y. M., Ab Kadir, M. Z. A., Kaka, U., Imlan, J. C., ... and Sazili, A. Q. 2016b. Bleeding efficiency, microbiological quality and oxidative stability of meat from goats subject to slaughter without stunning in comparison to different methods of pre-slaughter electrical stunning. *PLoS One* 12(5): e0178890.
- Sabow, A. B., Goh, Y. M., Zulkifli, I., Ab Kadir, M. Z., Kaka, U., Adeyemi, K. D., ... and Sazili, A. Q. 2019. Electroencephalographic and blood parameters changes in anesthetized goats subjected to slaughter without stunning and slaughter following different electrical stunning methods. *Animal Production Science* 59: 849-860.
- Sabow, A. B., Goh, Y. M., Zulkifli, I., Sazili, A. Q., Kaka, U., Ab Kadi, M. Z. A., ... and Adeyemi, K. D. 2016a. Blood parameters and electroencephalographic responses of goats to slaughter without stunning. *Meat Science* 121: 148-155.
- Sabow, A. B., Nakyinsige, K., Adeyemi, K., Sazili, A., Johnson, C., Webster, J. and Farouk, M. 2017. High frequency pre-slaughter electrical stunning in ruminants and poultry for halal meat production: A review. *Livestock Science* 202: 124-134.
- Sante, V., Le Pottier, G., Astruc, T., Mouchonière, M. and Fernandez, X. 2000. Effect of stunning current frequency on carcass downgrading and meat quality of turkey. *Poultry Science* 79: 1208-1214.
- Small, A., Lea, J., Niemeyer, D., Hughes, J., McLean, D., McLean, J. and Ralph, J. 2019. Development of a microwave stunning system for cattle 2: Preliminary observations on behavioural responses and EEG. *Research Veterinary Science* 122: 72-80.
- Velarde, A., Gispert, M., Diestre, A. and Manteca, X. 2003. Effect of electrical stunning on meat and carcass quality in lambs. *Meat Science* 63: 35-38.
- Velarde, A., Rodriguez, P., Dalmau, A., Fuentes, C., Llonch, P., von Holleben, K. V., ... and Cenci-Goga, B. T. 2014. Religious slaughter: Evaluation of current practices in selected countries. *Meat Science* 96: 278-287.
- Wagner, D. R., Kline, H. C., Martin, M. S., Alexander, L. R., Grandin, T. and Edwards-Callaway, L. N. 2019. The effects of bolt length on penetration hole characteristics, brain damage and specified-risk material dispersal in finished cattle stunned with a penetrating captive bolt stunner. *Meat Science* 155: 109-114.
- Warriss, P. D. 1977. The residual blood content of meat - A review. *Journal of Science Food Agriculture* 2: 457-462.
- World Organization of Animal Health (OIE). 2021. Slaughter of animals - Terrestrial animal health code. Paris: OIE.
- Wotton, S. B., Gregory, N. G., Whittington, P. E. and Parkman, I. D. 2000. Electrical stunning of cattle. *Veterinary Record* 147(24): 681-684.
- Yardimci, M. Y. 2019. Comparison of the stunning

and non-stunning slaughtering methods in the light of the current knowledge. *Journal of Veterinary and Animal Research* 2: 302

Zaman, R., Nassir, H. M., Abdurrazq, N. B., Salleh, H. M. and Rahman, M. T. 2012. Effects of different methods of slaughtering on protein expression in chicken meat. *IIUM Engineering Journal* 13(1): 27-34.

Zulkifli, I., Goh, Y. M., Norbaiyah, B., Sazili, A. Q., Lotfi, M., Soleimani, A. F. and Small, A. H. 2014. Changes in blood parameters and electroencephalogram of cattle as affected by different stunning and slaughter methods in cattle. *Animal Production Science* 54: 187-193.

Zulkifli, I., Wakiman, Z., Sazili, A. Q., Goh, Y. M., Jalila, A., Zunita, Z. and Awad, E. A. 2019. Effect of shackling, electrical stunning and halal slaughtering method on stress-linked hormones in broilers. *South African Journal of Animal Science* 49: 598-603.