PART 2

Literature Review

The Bleeding of Slaughtered Lambs for the Purposes of Halal Slaughter

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Preface

This literature review was written as the second part of the dissertation for my Masters in Meat Science & Technology from the University of Bristol, UK submitted in September 2011. With the grace of Allah (swt) I was awarded a Distinction and the Maurice Ingram Memorial prize for the student with the highest marks. This document is the same as the original submission with the exceptions of this preface, some late adjustments from Islamic scholars and some minor amendments for clarity & spelling.

Part 1 of the dissertation is a practical experiment carried out in an EC approved halal abattoir assessing differences in exsanguinated blood between lambs slaughtered using Electric Head-Only Stunning, Non-Stun and Post-Cut Electric Head-Only Stunning protocols for the purposes of Halal Slaughter. This is currently being prepared for publication in a scientific journal and will be released in due course.

Facilitating and promoting research in halal meat is my passion. I hope to encourage others to perform research in specific issues relating to the halal industry. Research must be conducted on a species specific basis. It also needs to clearly highlight the stunning and slaughtering protocols used as not all methods are the same and even within the same method, attention to details can make a difference. The author has observed very broad statements being made for 'all stunning methods'.

Thanks to Steve Wotton (my supervisor, University of Bristol, UK), Joe Regenstein (Cornell University, USA) and other scientists who have helped me by reviewing this work. Many thanks to the UK Islamic scholars who have commented on the Islamic aspects of this review. Thanks to the many stakeholders who helped me in putting both the practical and written parts of my dissertation together and commenting on my documents. Finally many thanks to my family and my wife, Unjum, without whose support and duas (prayers) I could not have done this work. Any errors are mine, so please point these out, and all praise is for Allah (swt). Thanks for reading.

Rizvan M Khalid October 2011

Contents Page

List of Tables & Figures Page

1 Introduction

The bleeding of slaughtered animals is important for a number of reasons. First, it enables the humane death of an animal. Second, it is important for meat and carcass quality (e.g. organoleptic and keeping quality). Third, for some consumers most importantly, blood is forbidden by their religion and thus the efficient drainage of blood is crucial for consumption of the resultant meat.

For Muslims consuming food that is Halal (meaning permissible) is a religious obligation. Riaz & Chaudry (2004, p8) stated the general principle: 'All foods are Halal except those that are specifically mentioned as Haram' (by the Qur'an and Hadith as interpreted by Islamic Jurists). In discussing lawful and unlawful meat Masri (2007, p134) outlined this as a basic principle. It appears to be derived from the Qur'an (5:1, 6:145, etc.) and various Hadith on the nature of prohibitions. However many jurists have advised Muslim consumers to be cautious, particularly in relation to meat production (which must follow specific Islamic rules) in non-Muslim societies, by ruling all types of meat and animals to be Haram unless proven Halal (e.g. Taqi Usmani (2004, p67)). Consequently some Muslims have raised doubts about the use of certain stunning methods because of the potential violation of two of the fundamental Halal criteria;

- The animal must be alive at the point of slaughter
- Blood must not be consumed

This report does not review stunning methods under various processes and parameters to ascertain whether the animal is alive at the point of slaughter – although such a literature review and any subsequent research will undoubtedly be of great benefit. Instead this review focuses specifically on the bleeding of lamb during Halal slaughter.

Taqi Usmani (2004, p83) laid out the general principle for the permissibility of stunning for Halal *'If it is shown conclusively that this is indeed the case [i.e. that stunning reduces pain to the animals], and that the animal does not die from being stunned, then it is permissible to use these methods. Otherwise it is not.'*

Electric Head-Only Stunning (EHOS) of lamb is accepted by many Muslim representatives as compatible with Halal criteria (ECFR, 1999; IHIA, 2010) because it is not known to kill any lambs. As far as the author is aware, there are neither scientific experiments (Velarde *et al*, 2002) nor published incidences in industry where lambs have died as a result of EHOS (although any information to the contrary would be welcomed). Nonetheless, similar to how anti-GM consumers have the right to demand GM-free products, Muslim consumers have regularly indicated that they should have the right to demand Non-Stunned (NS) meat products (HMC, 2011; EBLEX, 2010). Masri (2007) stresses the great emphasis Islam places on animal welfare.

A further potential option for Halal consumers is that of post-cut stunning. This option has the benefit that Muslim representatives know without any shadow of a doubt that the animal is definitely alive at the point of slaughter whilst also addressing the biggest potential welfare concern (i.e. how long the animal remains conscious after the cut and therefore for how long it could potentially be feeling pain). Post-Cut Electric Head-Only stunning (PCEHOS) has another advantage over EHOS in that blood splash (petechial haemorrhages) is severely reduced (Kirton *et al*, 1978).

Although many interpretations exist, it is becoming generally accepted that Captive-Bolt Stunning (CBS) (whether penetrative or non-penetrative) is incompatible with Halal criteria because some animals can die from the stun and the requirements for Food Business Operators (FBOs) to tag and segregate such animals do not provide sufficient assurance to Halal consumers. Furthermore, even though currently permitted by clause 5.4.6.5 of IHIA (2010), Non-Penetrative Captive Bolt Stunning (NCBS) is disallowed for animals greater than 10kg live-weight (LW) by Annex 1 Chapter 2 Point 1 of the new EU Regulation PATK (2009) (due to be implemented by 1 January 2013).

This literature review focuses on practices, scientific papers and opinions in relation to the bleeding of slaughter lambs during all types of Halal-compatible slaughter with a focus on NS and EHOS. It examines Islamic scripture (restricted to the Qur'an and the six major books of Hadith) in relation to the consumption of blood for food with references

to other religious scriptures as appropriate. It summarises widely held concepts by the Muslim community and industry practitioners and subjects these to scrutiny in light of scientific literature and scripture. Finally, it concludes with a summary and a guide to future research priorities in this field.

Schulze *et al* (1978) states '*The rules for animal welfare founded on scientific standards of evaluation mean for many of the regulated welfare concerns,..., a necessity to clarify individual scientific and subject-specific issues.*'. This applies to all scientific observations on animals. Many readers mistakenly apply results in one species to other species without allowing for inter-species differences. Similarly, effects of one stunning method are transposed to all stunning methods. In many cases comparisons are not appropriate. To make sound comparisons, differences between species and between stunning methods and processes are appropriately highlighted and any statements qualified.

Earlier versions of this draft report were circulated to prominent Islamic scholars and Halal stakeholders in the UK. Their valuable input was gratefully received. In this report references to lamb and sheep are used interchangeably unless otherwise indicated.

2 Exsanguination of Lamb

The Oxford Dictionary defines exsanguination as “the action of draining a person, animal or organ of blood.” Appendix A outlines the nature of sheep’s blood, its cardiovascular system and key organs. Warriss (1984) conducted the last major review on bleeding of slaughter animals and this report humbly attempts to build upon that.

2.1 Importance of Exsanguination

Rapid exsanguination is important to ensure early brain death and thus a humane slaughter (HSA, 2004). This is true for NS slaughter or for any stunned-slaughter method which does not kill the animal. Maximising blood-loss is also important when blood products are produced and for reducing the chemical oxygen demand of effluent discharge (Warriss, 1984). The sight of blood does not appear to affect an animal’s behaviour provided it is calm (Gregory, 2007, p239).

2.2 Methods of Exsanguination

Sheep are normally exsanguinated by a transverse neck cut although a chest cut is used in some places (Gregory, 2007). The neck cut severs all the major tissues in the neck (carotid arteries, jugular veins, oesophagus, trachea, associated neck tissues and nerves) without cutting the spinal cord. The New Zealand Non-Stunned ‘Gash Cut’ (NSGC) refers to a neck cut used during NS slaughter which also severs the spinal cord at the occipito-atlantal junction (Blackmore & Newhook, 1976). Cutting the spinal cord produces a still carcass (i.e. no post-cut convulsions) for bleeding and dressing (Warriss, 2010).

The chest stick is preformed near the heart but is not widely practiced due to the contamination of the fleece with blood. Spear-sticking is another New Zealand method where an incision is made in the side of the neck to cut the jugular veins and carotid arteries but leaving the oesophagus and trachea intact. The last two methods are not commonly used.

2.3 Effect of Exsanguination on Loss of Consciousness and Death

Death should be viewed as a process. Effective exsanguination starves the brain of oxygenated blood resulting in a humane slaughter. After an effective neck cut sheep become unconscious within 5-7s (FAWC, 2003) and display no visually evoked responses (i.e. lose cortical function) by an average of 14s (Gregory & Wotton, 1984). An effective chest stick has the advantage of reducing the time to death to an average of 4.5s (HSA, 2004). The phenomenon of 'ballooning', observed in cattle and calves, delays the onset of unconsciousness but has not been shown to occur in sheep (Gregory *et al*, 2006).

Animals are presumed not to feel pain when they are unconscious. Post-slaughter carcass convulsions, which can be quite animated, occur after brain-death and are not a sign of consciousness or sensibility in animals. A lack of oxygenated blood to the brain instigates brain death and releases centralised control over spinal reflexes. This triggers enhanced spinal reflexes causing involuntary, and sometimes violent, muscle contractions (Grandin, 2010; Khan, 1984). These contractions subside once spinal function decays following slaughter, or glycogen levels in the muscle are depleted, or the muscle becomes too acidic following the increased production of lactic acid during anerobic glycolysis.

2.4 Distribution of Blood in a Slaughtered Lamb

Measuring blood volume in the live animal is difficult. Scientists have attempted to quantify the distribution of blood lost during exsanguination, lost during dressing, retained in the offal and the blood that is left as residual blood in the meat (Table 1).

Table 1: Distribution of Blood in a Slaughtered Lamb

Distribution of blood	%	Source
Blood lost at exsanguination	50-65%	50% - Cited in Kirton *et al* (1981). 65% - Warris (unpublished data) cited in Warriss (1984). This relates to blood lost from vessels > 0.3-0.6mm diameter and is approximately 4% of the animal's LW.
Residual blood content in lean meat	1-4%	Warriss & Rhodes (1977) on beef (who also concluded that the average residual blood in meat in a butcher shop is 0.3%). A similar amount for lamb is expected as both are red meat species.
Blood lost during dressing from large vessels or trapped in the body cavity	10-15%	Warriss, Personal Communications
Blood retained in non-carcass tissue (spleen, lungs, liver, heart, kidney) including hide/skin	15-20%	Warriss, Personal Communications
Total blood in live lamb	**100%**	

3 Factors affecting Blood Lost at Exsanguination and Residual Blood

The major factors affecting bleeding include the blood vessels severed, size and patency of the sticking wound, orientation of the carcass (e.g. horizontal or vertical), cardiac arrest, vasodilatation or vasoconstriction in the capillary bed, tonic muscle contractions squeezing blood capillaries and vessels and clonic activity causing movement of blood towards the sticking wound (Gregory, 2005). Processing factors include time (to bleed) and dressing procedures (to allow blood to escape). Other factors include sheep health, LW, breed, sex, stress and hydration levels.

3.1 Bleeding - Blood Lost at Exsanguination

Most papers concentrate on the first 90-120s when assessing blood lost at exsanguination. Warriss (1984) stated that it is likely that when an animal is exsanguinated, the blood which is lost comes from vessels larger than approximately 0.3-0.6mm in diameter. For smaller vessels there is not enough pressure or too much surface tension to force the blood out (hence there is always blood left in small capillaries). He further stated that the factors which affect exsanguination can be either physiological or mechanical. Physiological factors are those that influence the distribution of total blood volume between peripheral vascular beds and central large vessels, while mechanical factors influence the drainage of blood from the vessels at sticking. Delayed bleeding does not significantly affect blood retention or meat quality (Warriss, 1984).

Electrical stimulation of the carcass on the bleed line ("electrical bleeding") can improve bleeding efficiency as well as control the risk of cold shortening occurring (Gregory, 2007, p205). Hopkins *et al* (2006) showed that a thoracic stick coupled with electrical stimulation (duration 40s, 10 or 14Hz, max 300V peak, 600mA, pulse width 0.5ms, unipolar waveform) on a lamb carcass bleeding vertically for 90s released significantly more ($P<0.05$) blood from the carcass. However, it is unclear whether the extra blood would have been retained in the meat or would have been released during carcass dressing in any case.

Anil *et al* (2004) conducted an experiment on 60 sheep (22-68kg) in Turkey to compare bleeding using different methods of Halal slaughter. Sheep had not been allocated to treatment groups on the basis of Live-Weight (LW) and, as it turned out, there was a significant difference in LWs between treatments. Consequently LW was included as a covariate during statistical analysis to adjust the mean blood-loss weight at 10s intervals. All sheep were restrained in a v-restrainer before being manually moved onto a table, neck cut in the lateral recumbancy position and then hoisted whilst collecting the blood. They found an adjusted average of 1.58kg blood from 30 NS sheep (av. LW 38.6kg), 1.62kg for 18 EHOS sheep (350V for 3s, av. LW 45.6kg) and 1.53kg for 12 Penetrative Captive Bolt Stunning (PCBS) sheep (av. LW 37.5kg). It was concluded that there was no (statistically) significant difference between treatments after 90s of bleeding (blood weighing approx 4% of LW). In addition the slaughter process did not result in any significant difference in packed cell volume (PCV). pH was recorded in neck muscle samples and there were significant differences in pH_{45MIN} and pH_{24HR} with EHOS being the lowest (5.1) followed by NS (5.7) and PCBS (6.2) for pH_{24HR} respectively. Colour was correspondingly darker with a higher pH.

Velarde *et al* (2003) slaughtered 21 NS (av. LW 20.3 $\pm$ 0.45kg) and 22 EHOS (av. LW 19.5 $\pm$ 0.43kg, 250V constant volts, 50Hz sinusoidal AC, 3s, dry scissor tongs) to assess bleeding, carcass and meat quality traits. All lambs were hoisted by one leg before cutting and the blood was collected for 60s (instead of 90s). The average weight of the blood lost for both treatments were 0.9 $\pm$ 0.03kg. Interestingly, they found blood loss relative to LW (BL%) and Killing-Out % (KO%) to be significantly higher ($P<0.05$) in EHOS lambs. Citing Warriss & Leach (1978) they postulated that the release of catecholamines due to EHOS and the associated peripheral vasoconstriction will expel more blood from smaller vessels and result in minimal residual blood in the muscles. However their conclusion indicates that this result should be treated with caution and Anil *et al* (2004) did not find a similar difference. Furthermore, in contrast to Kirton *et al* (1981), no carcasses with petechiae (blood splash), ecchymosis (speckling), haematomas and bone fractures were found in either treatment although the incidence of petechiae in hearts were significantly higher in EHOS. Colour (LAB), pH, chilling losses and carcass weight tested at 45min and 24hr were not found to be significantly different.

Kirton *et al* (1981) compared bleeding and blood splash in lambs slaughtered by NSGC (av. LW 31.4kg), EHOS (av. LW 31.3kg, 0.75A, 50Hz, 1.4s) and Electric Head-to-Back Stunning (EHBS) (av. LW 31.3kg). They were slaughtered prone on a table and, following bleeding for 120s, had blood loss weights of 1.32kg, 1.32kg and 0.58kg respectively. There was no difference between NSGC and EHOS but the EHBS treatment group released significantly less blood ($P<0.001$). However, they concluded that this blood was largely lost during the dressing process as there was little evidence of it being retained in the carcass. Ensuing research on residual blood content was conducted by Chrystall *et al* (1981) and is discussed later.

Warriss & Leach (1978) slaughtered 80 lambs (30-40kg) in 8 balanced groups permutating through different protocols. They were either (i) EHOS (90V) or CBS, (ii) slaughtered on a table or a cradle and (iii) pithed or not-pithed (affecting spinal cord function). They found that sheep bled significantly more ($P<0.01$) on a cradle (1,335g) than hanging on a bleed rail (1,223g). They also found significantly more ($P<0.05$) blood lost during EHOS (1,335g) than CBS (1,223g). Pithing (physical destruction of the brain and upper spinal cord) had no significant effect on exsanguination (note: this practice is no longer permissible for food safety reasons). There were no significant differences in residual blood between treatments and they concluded that there was no correlation between blood lost at exsanguination and blood retained in the meat. They attributed the difference in blood lost at exsanguination to blood retention in the internal organs although there was no significant difference in the weight of the plucks (heart, lungs and liver). The difference was postulated to relate to the action of the spleen (which is capable of containing one seventh of the entire blood volume in live sheep). The spleen was not weighed separately.

Blackmore & Newhook (1976) compared different slaughter methods (NSGC, CBS, EHOS) using a permutation of different animals (ewes and lambs). They found that NSGC ewes bled more than CBS ewes (no EHOS ewes were assessed) and that, similar to Warriss & Leach (1978), EHOS lambs lost more blood and lost it more rapidly than CBS lambs (no NSGC lambs were assessed).

3.2 Residual Blood in Meat

Hansard (1956) carried out a study for medicinal purposes on the Residual Organ Blood Volume of Cattle, Sheep and Swine where animals were slaughtered following a blow to the head (possibly a poleaxe). He reported estimated average residual blood values (ml of blood/100g fresh wt) between 1.2 and 1.9 for sheep loin muscle (Table 2).

Warriss (1977) concluded that methods used for the estimation of residual blood in red meat were generally imprecise, the factors controlling its amount inadequately defined and that there was no unequivocal evidence that large quantities of residual blood were detrimental to meat quality. The results of Warris & Leach (1978) were discussed earlier. Warriss (1978) suggested that the main factor determining the residual blood content of meat was the degree of physiological stress experienced during slaughter. Catecholamines (adrenaline and noradrenalin) released from the adrenal medulla and sympathetic nerve endings result in vasoconstriction of the vascular beds of the capillaries which results in less blood retention (note: adrenalin is a vasolidator at low concentrations but a vasoconstrictor at high concentrations). Warriss (1984) suggested that the vasoconstriction effect of adrenaline and noradrenalin in blood would result in minimal retention of blood in the small blood vessels. He stated from previous experiments that the residual blood content of lean bovine meat is 2 to 9 ml/kg muscle. Finally he concluded that there is no evidence that the amount of residual blood is affected by different slaughter methods.

Chrystall *et al* (1981), in a follow-on study to Kirton *et al* (1981), showed that there was no difference in the residual blood content of lamb Longissimus Dorsi (LD), the microbiological status of the meat and its tenderness using different slaughter methods (NSGC, EHOS, EHBS, Non-Stunned Neuromuscular Blocking Drug (NSND)). It is interesting to note that the drug which prevented muscle spasms at slaughter had no significant effect on the residual blood content of the LD. On average the haemoglobin content of the muscles was 0.6mg/g of muscle and was stated to be less than Warriss & Leach's (1978) results (0.89mg/g $\pm$ 0.38) due to different extraction methods being used.

3.3 Residual Blood in Major Organs

Hansard (1956)'s study provided residual organ blood values of sheep at different weights (Table 2) where animals were slaughtered following a blow to the head. The spleen and lungs contained the most blood (measured in ml blood/100g fresh weight). Interestingly approximately one-third and one-fourth of their respective weights were due to blood itself. The liver, kidney and heart also contained significant volumes of blood with the loin and g. muscle containing the least. This is reasonable as one would expect organs that are part of the cardiovascular system to contain more blood. The author could not find any other papers to discuss whether other methods of slaughter would result in similar levels of residual blood content in organs. It is important to bear in mind that many large blood vessels are cut during dressing procedures, when the internal organs are removed, which allows further release of blood not lost at exsanguination.

Table 2: Residual Blood Values (ml blood/100g fresh wt) of Sheep Organs (Mean ± SD) Summarised from Hansard (1956)

Approx Age	Old sheep Yearlings (>1yr)	Lambs 2-weeks
N	3	3
Animal Weight (lb)	111 ± 24	9 ± 3.5
(calculated) Animal Weight (kg)	50.3 ± 10.9	4.1 ± 1.6
Total blood vol (ml/100g)	5.9 ± 0.4	9.3 ± 0.9
Spleen (ml/100g)	34.7 ± 2.2	34.8 ± 1.8
Lungs (ml/100g)	26.6 ± 4.7	18.2 ± 2.2
Liver (ml/100g)	8.1 ± 1.5	9.6 ± 1.0
Kidney (ml/100g)	5.4 ± 0.6	5.6 ± 0.8
Heart (ml/100g)	5.1 ± 0.6	5.9 ± 0.6
Pancreas (ml/100g)	3.3 ± 0.9	3.1 ± 1.1
Adrenal (ml/100g)	3.2 ± 1.2	1.9 ± 0.2
Pituitary (ml/100g)	2.2 ± 0.3	2.0 ± 0.2
Loin Muscle (ml/100g)	1.2 ± 0.4	1.9 ± 0.8
G. Muscle (ml/100g)	1.1 ± 0.5	1.7 ± 0.4

3.4 Blood Splash and Speckling

Blood splash (petechial haemorrhages in the carcass muscle) usually occurs following electrical stunning. Speckling (petechial haemorrhages in the fat) also occurs. These occur in meat and offal. Blood splash is rarely found in NS lambs and is negligible in PCEHOS lambs. Kirton *et al* (1978) found that lambs slaughtered using PCEHOS (300V, 3s) had the lowest incidence of blood splash in their carcass ($P<0.01$). They found that EHOS raised blood pressure in lambs on average 3.5 times pre-stun levels. They suggested that the application of the current resulted in damage to small blood vessels and that the rise in blood pressure exacerbated the amount of blood which flows out of the damaged blood vessels into surrounding tissues. Kirton *et al* (1981) showed that there were negligible incidences of blood splash in NSGC and EHBS lambs whereas there was a significant ($P<0.01$) increase in EHOS lambs. EHOS results in a two- to threefold increase in blood pressure which is thought to cause the rupture of capillaries thereby releasing blood into the surrounding tissues. Blood splash according to the authors can be reduced by shortening the stun-to-stick times but cannot be eliminated completely.

The exact cause of blood splash has not been proven but there are four main theories that have been put forward (Gregory, 2005):

(i) Direct muscle stimulation from the application of an electric current forces muscle groups to contract at the same time, which is contrary to the normal physiological control of skeletal muscle. This abnormal muscle contraction tears the capillary bed rupturing the capillaries in the process

(ii) Histological studies have shown that blood vessels on the venous side of the capillary bed may be unduly fragile causing them to rupture under an increase in blood pressure.

(iii) Arteriolar dilation coupled with the engorgement of the capillary bed would encourage the rupture of blood vessels when put under pressure.

(iv) Intense generalised muscle body contractions can put the venous and arterial systems under excessive pressure. When veins are squeezed the increase in pressure can result in the rupture of blood vessels at the capillary bed.

3 Islamic Scripture in Relation to Blood as Food

Background information on Islam and its Scripture can be found in Appendix B. There are only a handful of references to blood as food in Islamic Scripture. In the Qur'an it is referred to in only four verses.

'He has forbidden you only the Maitah (dead animals), and ***blood,*** *and the flesh of swine, and that which is slaughtered as a sacrifice for others than Allah…'*

Surah 2 Al-Baqara (The Cow) Verse 173

'Forbidden to your (for food) are: Al-Maitah (the dead animals – cattle – beasts not slaughtered), ***blood,*** *the flesh of swine, and that on which Allah's Name has not been mentioned while slaughtering,…'*

Surah 5 Al-Maeda (The Table spread with food) Verse 3

'Say (O Mohammad sas): "I find not in that which has been revealed to me anything forbidden to be eaten by one who wishes to eat it, unless it be Maitah (a dead animal) or ***blood poured forth*** *(by slaughtering of the like), or the flesh of swine (pork)…'*

Surah 6 Al-Anaam (The Cattle) Verse 145

'He has forbidden you only Al-Maitah (meat of a dead animal), ***blood****, the flesh of swine, and any animal which is slaughtered as a sacrifice for others than Allah …'*

Surah 16 An-Nahl (The Bee) Verse 115

It can be seen that ***blood*** is expressly forbidden in verses 2:173, 5:3 and 16:115 and ***blood poured forth*** is forbidden in 6:145.

Ibn Kathir (d1373), producing one of the most preferred commentary of the Qur'an, explains of verses 5:3 and 6:145 that it is the *'flowing'* (i.e. blood lost at exsanguination) or '*free*' blood (i.e. blood that comes free from the meat, e.g. in a butchershop or whilst washing meat at home) that is forbidden in Islam. His commentary of verse 6:145 further states '...*"Poured blood was prohibited, but the meat that still has some blood in it is*

allowed.".' Therefore it can be seen that there was agreement among early scholars that residual blood in the meat remains and is permissible but it is the free blood that is forbidden. This is the view of the majority of their contemporaries. For example, Masri (2007, p145) states '*The Qur'an has judiciously circumscribed the prohibition only to that blood which flows out of the body after slaughter (daman masfuhan) (Qur'an 6:145). By this qualification, Islam has freed the Muslims from the practice of removing every particle of blood from the flesh in order to make it Kosher or Halal*.' It is known that to be Kosher meat must also be deveined, and soaked and salted within 3 days of slaughter to purge all residual blood (Regenstein *et al*, 2003).

Taqi Usmani (2004) in a section entitled '*Causing Blood to Flow Out*' provides the Islamic evidence for the requirement to make blood flow for domesticated animals slaughtered under one's control (i.e. not while hunting). Masri (2007) dedicates a section in his book on *'The Relative Significance of Bleeding and the Invocation of God's Name'*. On p153 he states '*..according to the dietetic laws of Shari'ah, the flesh of game hunted for food is lawful (Halal) if the Takbir [invocation] has been pronounced before shooting or setting the dogs and birds of prey after it – even though the animal dies before the hunter has had a chance to slaughter it.*' He argues that although there is much emphasis on bleeding the animal to render the meat as hygienically pure as possible the bleeding requirements are mollified in the case of hunting yet the requirement for Takbir remains. He further states on p155 '*Many other such Ahadith leave no doubt that a hunted animal is lawful to eat, even if it dies unslaughtered and that it makes no difference how long it has been dead – as long as its flesh has not putrefied and is hygienically edible.*'. Thus the emphasis on bleeding is secondary to the emphasis on Takbir. Not all scholars will agree on this point.

Another important Islamic principle to note is that one cannot make Haram what Allah (swt – meaning The Most Pure and The Most High) has made Halal and vice-versa (Qur'an 5:87-88, 6:138-144, 16:116). One question remains: Is there a limit on how much blood is permitted to be retained in the meat? Tafsir Ibn Kathir, in the commentary of verse 5:3, mentions the following hadith reported by Ahmad (d855) and Ibn Majah (d887).

Narrated Ibn 'Umar (May Allah be pleased with him): Allah's Messenger (peace be upon him) said, "Two types of dead animals and two types of bloods have been made lawful for us, the two types of dead animals are locust and fish (seafood), while the two types of bloods are the liver and the spleen"

Thus it can be seen that two important organs from the cardiovascular system – namely the liver where blood is processed, filtered and stored and the spleen where red blood cells are produced, stored and removed – are Halal. It was seen earlier that such organs contain far more blood cells per gram than muscle cells (Table 2). Therefore, it can be argued from a Halal perspective that the residual amount of blood permissible in meat should not exceed that normally found in the liver or the spleen. More detailed research could help establish the residual blood values of liver or spleen for different slaughter methods. Furthermore, we also know that red and white cells and platelets (components of blood) are produced in the bone marrow and in the absence of any references to the contrary bone marrow is considered Halal.

There are conflicting reports regarding the permissibility of cutting the spinal cord during Halal slaughter. Khan (1984) argues it is unacceptable because carcass convulsions are required to 'squeeze all blood out of the meat'. In contrast Gregory (2007, p207) stated that a minority of Halal slaughterman sever the spinal cord whilst a further minority also practiced decapitation. The author could not find any references about the issue in Islamic Scripture.

In summary it can be seen that effort must be made to release as much blood as possible from the animal but there is no threshold stipulated and the Islamic prohibition of blood is for '*flowing*' or '*free*' blood that does not extend to residual blood in the meat itself.

4 Conceptions about Bleeding and Residual Blood

There are many layman conceptions about the effects of slaughter methods on bleeding and residual blood and the implication for Halal consumers. The main ones are briefly discussed below. A statement is made, whether true or not, with examples of original references/quotes followed by discussions with respect to scientific papers, opinions and Islamic scripture. Statements stemming from the psychological effect of blood consumption are not discussed.

1) Blood is Haram. Therefore to be Halal there must be no residual blood in the meat.

- "*According to this holy verse (Sur'ah Al-Maidah verse 3) it is prohibited to eat:... any blood or blood inside the meat.*" (Katme, 2011)
- *"From an Islamic perspective it is Haram to eat meat containing blood."* (A Muslim, Personal Communications)

The statement draws an incorrect conclusion. As stated earlier only 'flowing' or 'free' blood is Haram. There is always some residual blood in the meat (even in NS meat) and this meat is permissible for Halal consumers. The salting process to extract residual blood from [NS] Shechita (Regenstein *et al*, 2003) would not be needed if there were no residual blood. Islamic scholars unanimously accept residual blood (Ibn Kathir, d1373, 6:145; Masri, 2007, p134&145). Warriss & Rhodes (1977) estimate 1-4% of a live animal's total blood volume (at 100%) is retained in the meat.

2) Halal slaughter methods must extract the maximum amount of blood from the animals.

- *"Haram Animals (are) ....Animals killed in a manner which prevents their blood from being fully drained from their bodies."* (HMC, 2001) www.halalmc.net/resources/what_is_halal.html, www.halalmc.net/resources/stunning_articles/008_draining_the_blood.html
- *"It is therefore essential that the method employed in killing an animal for food should ensure the maximum extraction of blood from the meat."* (Khan, 1983, p7)

This statement is true as a principle but not as a detailed procedure. Whatever slaughter method extracts a greater amount of blood is likely to be seen as superior from an Islamic perspective. However, there is no minimum amount specified as to how much blood should pour forth or how much residual blood is acceptable. Further questions could arise as to whether the kosher-salting of meat (which extracts residual blood) would be seen as superior from an Islamic perspective. This is unlikely to be the case as there is no evidence showing this to be a practice of the Prophet Muhammed (pbuh) or his Companions (those that followed him) even though it was likely practised by the Jews of the time (Rabbi Joel Roth, Personal Communication). Additionally modern technology makes possible the electrical stimulation of carcasses on the bleeding line thereby extracting more blood on the bleed line. This was demonstrated by Hopkins *et al* (2006) and could potentially be seen as a superior method for Halal meat production. However Warriss & Leach (1978) showed there was no link between blood lost at exsanguination and residual blood in the meat.

3) NS meat bleeds better and results in less residual blood than 'stunned' meat.

- *"Religious slaughter causes a rapid draining of bacteria and hormone-carrying blood from an animal's body which is critical to healthy, blood-free meat"*. (A Muslim, Personal Communication)

First, discussing statements about 'stunned' meat is counterproductive – rather the type of stunning being discussed should be defined. Anil *et al* (2004) did not find any difference in 90s bleed-out between NS, EHOS and CBS. Warriss (1984) came to similar conclusion. Velarde *et al* (2003) found EHOS to bleed significantly more than NS (in terms of Bleed-Out %) but concluded that there was no difference overall. In terms of residual blood Kallweit *et al* (1989) did not find any difference between EHOS (250V, 50Hz, 10s), NS Halal and NS Shechita. As discussed earlier there is no proven link between blood lost at exsanguination and residual blood in the meat.

4) **Stunning affects bleeding by (i) causing blood splash, (ii) reducing the flow and amount of blood at exsanguination and (iii) adversely affecting the muscles which help expel blood. Stunning also results in a higher pH_{ult} which reduces its shelf-life. Overall stunning leads to greater blood retention in the meat.**

- *"(Pre-stunning)... causes blood splash into muscles and more harmful blood stays inside the meat"* (Khan, 1982, p34 attributing these ideas to Gilbert & Blackmore).
- *"Stunning prevents the drainage of entire blood resulting in it being retained."*, *"It is also proven that a large amount of blood remains in the animal...."*, *"Retained blood causes germs and bacteria"* HMC's 'Quick Facts' on stunning (www.halalmc.net/resources/issue_stunning.html).
- *"Concerning stunning and its effects on bleeding, it is a fact that all methods of stunning produce neurogenic shock, a condition in which blood leaves the circulation. In this condition, the nerves which regulate the size of the blood vessels are paralyzed. Blood fluid then leaves the circulation and enters the inter-cellular spaces in the tissues. When such an animal is bled, this fluid is not available for expulsion into the circulation and finally out through the wound"*. (Khan, 1982, p18).
- *"Electrical stunning hastens the onset of putrefaction in meat. The explanation of the phenomenon lies in the high lactic acid level (pH_{ult}) following electric shocks and prior to bleeding. High lactic acid alters the bacterial resistance of meat."* (Khan, 1982, p17)

Again making general 'stunning' statements is counterproductive. This response is restricted to EHOS of sheep. CBS can kill the animal whereas EHBS is designed to kill the animal hence neither is discussed in the context of Halal. Appendix C provides background information on EHOS of sheep.

It is known that blood splash occurs after EHOS of sheep (Kirton *et al* (1981)) but it does not occur in every animal with the percentage of animals with splash varying widely between plants (e.g. 3% - 25%). The mechanism by which blood splash is thought to occur has already been discussed. Blood splash is residual blood which has escaped from blood vessels into surrounding muscle tissues. It rarely occurs in NS lambs and is negligible in PCEHOS lambs (Kirton *et al* 1978).

It was concluded earlier that NS and EHOS lambs bleed the same by the end of the normal period of bleeding (90-120s) and there is no statistical difference in blood flow rate. The tonic and clonic convulsions experienced by EHOS lambs are discussed in Appendix C. In NS lambs the animal becomes limp (and not rigid) after slaughter and before post-brain-death convulsions. Kicking can be more violent in NS lambs compared to EHOS thus making it potentially more dangerous to handle the carcasses. There is little evidence to suggest that the amount and intensity of kicking influences blood lost at exsanguination or residual blood content although further research would be welcomed.

It is known that a high pH_{ult} reduces meat shelf-life by providing an environment more conducive to microbial spoilage. Whether EHOS leads to a high pH_{ult} in muscles has not been adequately researched. Grandin (2010) and Gregory (2007) did not comment on the effect on pH. The author has come across contradictory experiments. Neither Vergara *et al* (2005), Anil *et al* (2004), Velarde *et al* (2003) nor Chrystall *et al* (1981) observed a high pH_{ult} in EHOS compared to NS. However Linares *et al* (2007) did find significantly lower ($P<0.001$) pH_{7days} post-mortem in NS compared to EHOS and GSL. Similarly Vergara & Gallego (2000) found pH_{14days} significantly lower in NS compared to EHOS. It should be noted that there are a multitude of different parameters which affect pH. Further research focusing on pH in the context of slaughter methods would be welcomed.

Warriss (1978) suggested that the stress associated with EHOS and exsanguination will normally produce peripheral vasoconstriction through released catecholamines which will expel blood from the blood vessels and result in minimal residual blood. Chrystall *et al* (1981) found no evidence that EHOS results in higher residual blood levels in meat.

5) A beating heart is required for maximum bleeding. If cardiac arrest occurs there is stagnation of blood in the carcass resulting in greater residual blood. Electrical stunning can affect the beating of the heart.

- *"..the stronger the heart beat and the longer it goes on beating, the greater will be the quantity poured in circulation, but the heart can eject only as much as it received from the tissues."* (Khan, 1983, p11)

A beating heart is not necessary for maximising blood loss. Severance of major blood vessels in the neck will result in a catastrophic fall in blood pressure with a resultant fall in cardiac output. If the heart is to remain viable as a pump, venous blood pressure must be maintained in order for the heart to refill during diastole. Although it may carry on beating for more than 10 minutes after slaughter (Newhook & Blackmore, 1982) the heart's function as a pump ceases once the venous pressure drops below critical limits but little research has been conducted to establish the time at which this occurs. Warriss (1984) stated that a beating heart is unlikely to directly affect the drainage of blood from the carcass.

EHBS is designed to both stun the animal and induce a cardiac arrest. As discussed earlier Kirton *et al* (1981) concluded that there was significantly less blood lost at exsanguination following cardiac arrest but this blood was not retained in the carcass and was largely lost during the dressing process. EHOS does not produce a cardiac arrest as the stun applicator targets the brain only. Furthermore current frequency can be adjusted to ensure there is a negligible chance of cardiac arrest occurring (See Appendix C).

6) Carcass convulsions are required to maximise bleeding. Cutting the spinal cord on slaughter reduces blood lost at exsanguination and increases residual blood.

- *"...this is why the spinal cord is not cut in dhabh....Convulsions produce the squeezing or wringing action of the muscles of the body on the blood vessels which helps to get rid of the maximum amount of blood from the meat tissue into the circulation."* (Khan, 1983, p10).
- *"If the spinal cord is cut, the nerve fibers to the heart might be damaged leading to cardiac arrest thus resulting in stagnation of blood in the blood vessels"* (El-Awady, 2003)

The requirement not to sever the spinal cord for Halal has not been identified from Islamic Scripture. Warriss & Leach (1978) concluded that for EHOS and CBS lambs pithing statistically affects neither blood lost at exsanguination nor residual blood in the muscle. The results from Chrystall *et al* (1981) showed that NSND, which suppressed muscle spasms, did not result in statistically less residual blood compared with those measured

with NSGC and EHOS. It would however be interesting to compare NS (where the spinal cord is not cut) with EHOS and PCEHOS. The author could not find any papers addressing this question and so further research would be welcomed.

7) Blood consumption promotes disease and infection. The greater the residual blood in meat the greater the chances of food-borne disease and the shorter the shelf-life.

- *"The blood must be drained completely before the head is removed. This purifies the meat, as the animal's blood acts as a medium for microorganisms. Meat also remains fresh longer as compared to other methods of slaughter"* (El-Awady, 2003)
- *"It's forbidden to consume blood, in any form, and, medically, we know that blood is harmful to health. As it contains toxins and urea, and may contain bacteria, parasites, viruses, new chemicals and drugs etc. Besides this, blood can lead to poisoning when still in meat to be consumed."* (Katme, 1986).
- *"Blood carries organisms responsible for various diseases. These organisms circulate in the blood without the body manifesting any symptoms of the disease, a condition called sub-clinical infection. It is therefore harmful to consume blood..... Also if meat containing much blood is consumed, there is a potential danger of contracting diseases produced through the organisms in the blood."* (Khan, 1982, p7)
- *"It is pertinent to state here that meat without blood ...preserves better. On the other hand, the presence of blood in meat influences its putrefaction. Micro-organism find the blood a fertile ground in which to grow. The greater the amount of blood remaining in meat granules, the quicker will organisms proliferates and the sooner will the meat start putrefying."* (Khan, 1982, p11)

Blood is sterile in a healthy animal. It is a transport medium and so will contain waste products as well as nutrients. The author has not come across any evidence that meat-borne microbes prefer residual blood to the lean meat itself so there is no reason to suggest that microbes would flourish in meat with high residual blood. At what point meat contains ***too*** much blood has not been determined and there is no threshold value known at which spoilage is accelerated because of blood in the meat or organ.

Chrystall *et al* (1981) showed that there was no difference in the microbiological status of the meat obtained using different slaughter methods (NSGC, EHOS, EHBS, NSND). They did this by (i) assessing total microbial counts in the samples over 14d and (ii) inoculating separate meat samples with a pure culture to assess the growth rates of *M. thermosphactum* and *Pseudomonas* over 4d.

Warriss (1984) states *"There is no evidence that this amount (the residual blood content of meat) is affected by different slaughter methods or that large amount of residual blood influence the microbiology of meat".* Citing Roberts (1980) he said that there appears to be no relation between the keeping quality of meat and the degree of bleeding out. However, he further stated that a dirty slaughter knife can lead to contamination of the deep parts of the carcase of sheep through a functioning circulatory system. Riaz & Chaudry (2004, p12) states that 'Blood that is drained from the body contains harmful bacteria, products of metabolism, and toxins.' This is similarly postulated by Regenstein *et al* (2003).

Finally, the author has not identified any papers which suggests that kosher meat (known to have minimal residual blood) has a longer shelf-life, although it would probably be expected to do so because the kosher salting process would lower meat a_w (water activity).

8) The less the residual blood in meat the better the meat quality and taste.

- *"It is pertinent to state here that meat without blood tastes better..."* (Khan, 1982, p11)
- *"In 1955, the Danish Ministry of Justice issued a circular exempting the use of electric stunning for pigs. This was in response to a petition from Danish meat packers which said that 'Stunning with electricity causes extra vasation in meat, sanguinary intestines and fracture in the spinal column, pelvis, and the shoulder blades through shock. The blood in the meat makes it more susceptible to putrefaction and has a detrimental effect upon its taste. The properties of the meat which would cooperate with the salt in euracting the blood traces are interfered with in the animal undergoing shock convulsions prior to slaughter'."*(Khan, 1982, p16)

There are many parameters that make up 'meat quality', and many more that affect it, so a detailed explanation is not possible in this review.

Linares *et al* (2007) compared NS, EHOS (110V, 50Hz, 5s) and GSL (90% CO_2, 90s) (10 lambs per treatment) for any effects on meat quality parameters (pH_{24}, colour coordinates, water holding capacity (WHC), cooking loss (CL), shear force (SF) and drip loss (DL)). No difference was found in 24 hours however at 7 days pH_{7days}, CL and DL were significantly lower ($P<0.001$) in NS. It is not stated how the NS lambs were restrained for slaughter.

Vergara *et al* (2005) also assessed meat quality (pH, colour, WHC, CL, SF, DL). They did not find any difference in pH_{7days} between NS (details not sufficiently described), EHOS (110V, 50Hz, 5s) and GSL (90% CO_2, 90s). In general the slaughter methods did not affect colour, WHC and CL. The SF results indicated that the GSL was most tender ($P<0.01$) with ESL and NS statistically similar. DL_{7days} was significantly higher ($P<0.001$) in NS compared to GSL and EHOS.

Vergara & Gallego (2000) assessed pH, colour, WHC and SF and found that NS (details not sufficiently described) had a pH significantly lower ($P<0.05$) than EHOS (125V, 10s) but there was no effect on colour, WHC and SF. Chrystall *et al* (1981) (discussed earlier) showed that there was no difference in tenderness of M. longissimus dorsi muscle between different slaughter methods.

There appears to be no research on differences in meat flavour after different slaughter methods. More research on meat quality parameters (including taste) following best-practice Halal slaughter using NS, EHOS and PCEHOS would be welcomed.

5 Conclusion

This paper reviews existing literature in relation to the bleeding of slaughtered lambs for the purpose of Halal slaughter. Many different stunning and slaughter methods are used in industry and care must be taken when applying findings to either a general or a specific scenario. Furthermore inter-species differences must be highlighted and statements qualified as necessary.

Exsanguination is a necessary step in the slaughtering process. After an effective neck cut sheep generally lose unconsciousness within 5-7s (FAWC, 2003) and cortical brain death occurs in approximately 14s (Gregory & Wotton, 1984). Post-brain-death convulsions occur after death and are not a sign of consciousness. Given a live sheep's blood volume as 100%, approximately 50-65% is lost during exsanguination and 1-4% remains in the meat with the remainder retained in the viscera and lost during dressing.

The major factors affecting bleeding are the blood vessels severed, size & patency of the sticking wound, orientation of the carcass (horizontal or vertical), cardiac arrest, muscle contractions, time (to bleed) and dressing procedures (to allow blood to escape). Blood lost at exsanguination normally completes by 90 – 120s post cut. Anil *et al* (2004) focusing specifically on Halal slaughter did not find any difference in blood lost at exsanguination between NS and EHOS during 90s. Similarly Velarde *et al* (2003) did not find any difference. Kirton *et al* (1981) compared NSGC, EHOS and EHBS and found no difference in exsanguinated blood between NSGC and EHOS but EHBS was significantly lower. They attributed this to trapped blood that was lost on further dressing. Follow-up studies by Chrystall *et al* (1981) on the same slaughter methods concluded that there was no difference in residual blood content between treatments. Residual blood in meat does not seem to vary between slaughter treatments and is not correlated to the amount of blood lost at exsanguination (Warriss & Leach, 1978). Hansard (1956) carried out a study for medicinal purposes and reported residual blood values for major organs and the loin muscle of sheep. The spleen and lungs contained the most blood which represented one-third and one-fourth of their respective weights. The liver was the next highest. However,

no further studies on residual blood in organs could be found for comparative discussions.

From Islamic Scripture it can be seen that effort must be made to release as much blood as possible from the animal but there is no threshold stipulated and the Islamic prohibition of blood is for *'flowing'* or *'free'* blood which does not extend to residual blood in the meat itself.

Common layman conceptions, mostly false and misleading, about bleeding and its effect on blood lost at exsanguination and residual blood were discussed. There will always be some residual blood left in meat and this is permissible according to Islamic Scripture. There is no evidence to support the theories that, compared to EHOS, NS meat bleeds better, results in lower levels of residual blood, has a longer shelf-life and has better meat quality traits (such as taste). A beating heart is not necessary for efficient bleeding, with any blood not lost at exsanguination likely to be released during the dressing procedure, and is unlikely to directly affect residual blood in the carcass (Warriss, 1984). Blood splash, whose histology is similar to residual blood, occurs in EHOS but is severely reduced in PCEHOS. There is insufficient literature regarding differences in carcass convulsions and meat quality parameters to fully verify or otherwise test many of the statements made.

It is recommended that future research priorities for Halal slaughter of sheep should include the following.

- Develop best practice Halal slaughter protocols for each of the methods (NS, EHOS, PCEHOS) in accordance with PATK (2009).
- Investigate the time, following a ventral neck cut, at which venous pressure to the heart is lost thereby disabling its function as a pump.
- Assess experimentally the residual blood content of lean meat and major organs following different slaughter methods i.e. NS, EHOS and PCEHOS.
- Compare the effect of carcass convulsions on residual blood following the different slaughter methods (NS, EHOS and PCEHOS) including a step which severs the spinal cord (or not) for each treatment.

- Assess experimentally the various meat quality parameters (e.g. pH_{ult}, taste, colour, WHC, DL, SF and shelf-life) of different muscles following different slaughter methods (NS, EHOS and PCEHOS).
- Conduct a literature review of stunning methods, processes and parameters to ascertain whether animals are definitely alive (a practical definition would be required) at the point of slaughter all of the times.
- Assess experimentally the recoverability of EHOS sheep for increasing levels of amps/volts to determine the threshold at which sheep start to die and thus recommend optimum stun parameters for Halal whilst incorporating a significant safety buffer.

Appendix A: Blood, the Cardiovascular System and Key Organs

Grist (2010) describes the sheep's anatomy in detail. This is summarised below with references to additional literature included as necessary.

BLOOD

Blood is a high viscosity red fluid consisting of plasma, red cells, white cells and platelets. Most of the blood cells (red cells, white cells and platelets) are created in the bone marrow by a process called haematopoiesis. The pH of blood is highly buffered within a pH of 7.35 – 7.45. Blood clots rapidly on exposure to air.

Plasma: Plasma is a straw coloured protein rich fluid containing water, salts, nutrients, hormones and waste products of cellular metabolism. It represents approximately 54% of blood by volume.

Red Cells: Red cells, also known as erythrocytes, do not possess a nucleus. Each cell carries haemoglobin – a protein which readily converts to oxyhaemoglobin. Haemoglobin (an iron-containing protein) picks up oxygen from the lungs and transports it to the cell tissues where it is needed. Carbon dioxide (a waste product) is almost entirely transported extracellularly - dissolved in plasma as bicarbonate ion – and removed from circulation by the lungs. Healthy red cells have a plasma life of about 120 days before they are degraded by the spleen and the Kupffer cells in the liver. They represent approximately 45% of blood by volume.

White Cells: White cells, also known as leucocytes, are part of the immune system identifying and digesting foreign material such as bacteria, neutralising toxin and removing dead/damaged tissue. They represent approximately 0.7% of blood by volume.

Platelets: Platelets are cells that participate in the clotting mechanism. They possess no nucleus.

CARDIOVASCULAR SYSTEM

The cardiovascular system refers to the heart, blood and blood vessels. It is a sealed system of tubes through which blood is pumped by the heart. It is essentially the body's transportation system; carrying items to tissue cells such as food, messages and protection whilst also removing waste products.

Blood Vessels

Blood vessels carry blood around the body. Arteries carry blood under pressure from the heart whilst veins carry blood back to the heart. Arteries branch to arterioles to capillaries to venuoles and finally to veins for returning to the heart. Capillaries are different in that a proportion of the muscle in the wall is used to regulate blood flow. Blood leaves the vessel to bathe the tissue cells before returning to the capillaries. Veins are thinner walled than arteries as they are not exposed to the effects of the ventricular contraction of the heart. Arteries have a 3-layered wall which allows for expansion of the artery during the contraction phase (systole) followed by elastic relaxation (ventricular diastole) and return to normal size during the rest phase (an action which also propels the blood along the artery).

KEY ORGANS

Heart

The heart muscle, i.e. cardiac muscle, is a specialised form of musculature which is different from normal skeletal muscle. It has an aorta, left auricle and ventricle, right auricle and ventricle and coronary furrow. The left side has thicker walls and supplies arterial blood to the body under systolic pressure. The right side supplies deoxygenated blood to the lungs

Liver

The liver can be considered the chemical and filtration organ of the body. Glycogen is stored after conversion from glucose by recombination and release into the bloodstream. Most plasma proteins, and essential blood clotting factors, are produced in the liver. Urea is produced in the liver (after protein deamination) and enters the bloodstream for eventual removal by the kidneys. The liver's Kupfer cells remove bacteria and other invasive organisms from the blood.

Spleen

The spleen (or melt) is a greyish-blue organ which consists of a firm capsule enclosing red and white pulp. The red pulp produces red blood cells and acts as a blood storage reservoir. The white pulp adds lymphocytes and removes old and diseased red blood cells and particulate matter from blood. Macfarlane (1975, p8) states 'The spleen of (live) sheep stores 500-800ml of concentrated red cells which can be released to the circulation when sheep are feeding or are disturbed'. Warriss & Leach (1978) states that the spleen 'is capable of containing up to one-seventh of the total blood volume in (live) sheep'.

Lungs

The lung is part of the respiratory system where air is drawn in (oxygen demand) and carbon dioxide is exhaled. Gaseous exchange occurs in the alveoli, the microscopic terminal sacs also known as air sacs. Air diffuses through the wall of the alvioli into the blood where oxygen binds to haemoglobin to produce oxyhaemoglobin. Simultaneously carbon dioxide is released from the blood plasma into the alveoli for expulsion.

Kidneys and the Urinary System

The main function of the urinary system is the filtration of toxic substances, including urea, from the blood and then excreting them from the body. The kidneys actively secrete waste products into the urine.

Appendix B: Islam and Scripture

Islam

Islam, as one of the 3 Abrahamic faiths, is a continuation of Judaism and Christianity. It is the 2nd largest religion in the world after Christianity. The pure Abrahamic faiths all believe in the early Old Testament prophets including Adam, Noah, Abraham (and sons) and Moses (peace be upon them all). Differences emerge with Jesus (peace be upon him (pbuh)) (known as Isa in Islam) whom Christianity and Islam rank as the son of God and prophet of God respectively. Additionally Islam recognises Mohammed (pbuh) to be the final prophet of God and the leader of all prophets.

The key beliefs and tenets of Islam can be found at www.islam-guide.com . The followers of Islam are known as Muslims. The Islamic Calendar starts from the year that Muhammed (pbuh) left Makkah for Medina; an event which is known as Hijarh (0 AH = 622 CE). Muhammed (pbuh) passed away in 10AH. The key holy scriptures in Islam are the Qur'an and the Hadiths.

Qur'an

The Qur'an is considered by Muslims as the literal word of God (Allah) as revealed to the Prophet Muhammed (pbuh) through the angel Gabriel (Jibril). It was preserved during the life of Muhammed (pbuh) largely through memorisation (as was the norm of the story-telling Arab Bedouins) and by writings on bits of material. Muhammed (pbuh) passed away in 10AH and was succeeded in order by the Khulafa Rashidun (the four rightly guided Caliphs – Abu Bakr, Umar bin Khattab, Uthman ibn Affan, Ali ibn Abi Talib). Abu Bakr (ruling 10AH – 12AH) comprehensively compiled the writings of the Qur'an. Uthman ibn Affan (ruling 22AH – 35AH) consolidated the Qur'an as the Muslim empire grew by having all known manuscripts destroyed and replaced with verified Qur'anic reference manuscripts.

The Qur'an has been persevered from the time of Muhammed (pbuh) to the current day and can be explored at www.quranexplorer.com. Today many English translations exist of

the Qur'an. The author uses the Mohammed Mohsin translation as the one he is most familiar with. The constraints of translating one language to another must be recognised and therefore such translations are commonly referred to as a 'translation of the interpretation of the Qur'an'.

The Qur'an is interpreted using the recognised Tafsirs (exegesis). Tafsirs are commentaries on the verses of the Qur'an - explaining them in more detail. The most famous Tafsir is that of the pious predecessor Ibn Kathir (1301-1373) who lived in Damascus. The author could not find the precise year his Tafsir was finished but it can be explored online at www.qtafsir.com . Other famous Tafsir's include Tafsir Qurtubi and Tafsir at-Tabari.

Hadith

Ahadith are known as the collective sayings, actions or observations of the Prophet Muhammed (pbuh) as narrated by those who knew him (hadith – singular).

Hadiths consist of a *matn* (actual text of the hadith) and an *isnad* (chain of narrators). The science of hadith evaluation evolved from a critical review of the hadiths in existence years after the death of Muhammed (pbuh). The *matn* was analysed for internal consistency and consistency with the Qur'an and other accepted hadiths. The *isnad* was analysed by establishing a definite chain of narration, assessing the reliability of each of the narrators in the chain and verifying that the narrators did actually meet each other.

Generally speaking the hadiths were classified by hadith scholars into relatively simple groupings (depending on the classification system and criteria used by individual hadith authors)

- *Sahih* (those hadith with the highest reliability)
- *Hasan* (sound hadith that have not reached the level of Sahih)
- *Daif* (weak hadith in that the hadith *matn* and *isnad* have been verified but there are no other corroborating hadiths to raise the level of assurance about the hadith (e.g. isolated hadiths))

- *Fabricated* (those hadith that are shown to be lies).

The most famous books of hadith are known as *al-Kuttub al-Sitta* (the six books of Hadith collections). They are

- *Sahih Bukhari* by Imam Bukhari (d 256AH/ 870CE)
- *Sahih Muslim* by Muslim b. al-Hajjaj (d 261AH/ 875CE)
- *Sunan ibn Majah* by Ibn Majah (d 273AH/ 887CE)
- *Sunan Abu Dawood* by Abu Dawood (d 275AH/ 889CE)
- *Jami al-Tirmidhi* by al-Tirmidhi (d 279AH/ 892CE)
- *Sunan al-Sughra* by al-Nasa'I (d 303AH/ 915CE)

After the Qur'an the two Sahih books (*Sahih Bukhari* and *Sahih Muslim*) are known as the most authentic books of scripture.

Not all hadiths are currently available online. Some of them can be explored at www.quranexplorer.com or http://ahadith.co.uk.

Appendix C: Electric Head-Only Stunning of Lamb

"Death is a process and does not occur immediately" (Grandin, 2010).

The purpose of stunning is to render an animal immediately unconscious until death is induced by exsanguination. Some stunning methods can themselves result in death.

Gregory (2007) states *'Head-only electrical stunning is reversible. In other words the animal can regain consciousness. This has two consequences. First the animal has to be killed soon after head-only stunning to ensure it does not recover. Secondly, head-only electrical stunning can be acceptable to some Halal slaughter authorities as it does not kill the animal.'*

Unconsciousness means different things to different people. PATK (2009) states in preamble paragraph 21 that *'...an animal can be presumed to be unconscious when it loses its natural standing position, is not awake and does not show signs of positive or negative emotions such as fear or excitement.'.*

Sensibility is different from consciousness and here again PATK (2009) states in the same paragraph *'In general, an animal can be presumed to be insensitive when it does not show any reflexes or reactions to stimulus such as sound, odour, light or physical contact.'.*

Practically speaking an animal can be presumed to be insensible to pain if it is unconscious. Post-slaughter carcass convulsions occur after cortical brain death and are not indicative of consciousness in animals. The stunning process, performed correctly, should protect the animal from the potentially painful experience of slaughter; therefore the unconscious animal should not feel pain.

Gregory (2007) states the criteria that have been used most for the purposes of assessing stunning methods.

- Presence of an electroplectic fit
- Presence of EEG amplitudes and frequencies that are symptomatic of unconsciousness
- Absence of primary evoked cortical responses in the brain
- Behavioural signs such as collapse, seizure and absence of brainstem reflexes.

Electricity and its Effect on Animals

Generally speaking electricity will obey Ohm's law: Voltage (V) = Current (I) x Resistance (Ω) (Voltage is measured in volts (V), current in amps (I) and resistance in ohms (Ω)). However, during electrical stunning of animals, research by Wotton and O'Callaghan (2002) on pigs has shown that the resistance of live tissue is dependent on the magnitude of the applied voltage. It is interesting to note that the majority of farmed fish in the UK are now electrically stunned. Mains voltage in the UK is generally 220-240V.

Traditionally it was believed that the ***current*** stuns an animal (i.e. renders it unconscious through the induction of an epileptic fit) however, recent research would suggest that the ***voltage*** field is particularly important. When current is applied to an animal the current field spreads steadily through the animal over time. One side-effect of electrical stunning is the direct stimulation of muscles to contract; even those muscle groups that are agnostically opposed. Theoretically it is thought that muscle contraction following application of an electric current occurs in one of three ways

- direct muscle stimulation (particularly as a current field spreads over time)
- stimulation of the motor cortex of the brain (the part of the brain that physiologically controls muscle contraction)
- stimulation of peripheral motor nerves (muscle control centres outside of the brain)

Frequency is the number of electric cycles of AC (alternating current) per second. UK mains frequency is 50Hz which is the most efficient frequency at which electricity can be

transported through the national grid. Different muscles contract in different ways to currents applied at different frequencies. One can avoid or minimise direct muscle stimulation by increasing the frequency of the applied waveform. The target organ for stunning, the brain, will respond to frequencies up to 10,000 Hz whereas skeletal muscle does not respond much above 1500Hz. Most importantly for Halal, it is difficult to induce a cardiac arrest (by simultaneous contraction of cardiac muscles) at frequencies higher than 100Hz (AWTC, 2008) (for water-bath stunning of turkeys this is 500Hz (PWTC, 2010)). Therefore, frequencies at 200Hz or above are recommended as an additional assurance for Halal slaughter of sheep. Furthermore higher frequencies are known to reduce the amount of blood splash or blood speckle in the animals (Wotton, Personal Communication). There is a trade-off with using higher frequencies. Although animal recovery is unaffected the animal exhibits greater post-stun kicking which makes it more difficult for the operators to handle the animals when they are hanging on the bleeding line.

Electric Head-Only Stunning (EHOS) is not to be confused with Electric Head-To-Back Stunning (EHBS) where a current is also applied to the heart, stimulating ventricular fibrillation and resulting in cardiac arrest (i.e. death). EHBS promotes the start of the death process to the time of the stun application thus the animal cannot regain consciousness before death occurs.

Side-point

Electricity can be deployed positively in therapy and/or life-threatening situations. Examples include defibrillation, neuromuscular electrical stimulation and electroconvulsive therapy. It can be used for capital punishment. Electrocution is an electric shock that can end life, usually by stopping the heart. Generally speaking electricity terminally affects the heart first before affecting the brain. Electrocution is used for capital punishment in some US states but its use is in decline due to botched electrocutions and the rise of the use of lethal injection (widely believed to be more humane). In an electric chair the person being killed is electrocuted through electrodes placed on the body with various cycles (differing in voltage and duration) of AC causing fatal damage to the internal organs. The cause of death was frequently assessed as

electrical overstimulation of the heart. The current Nebraska protocol requires 2,450V for 20s.

Electrical Stunning and Meat Quality

Electricity can have a detrimental effect on meat quality, particularly causing the presence of blood splash and blood speckle (Gregory, 2007). It can also result in broken bones and other haemorrhages, brought about by the force of muscle contraction as a result of direct muscle stimulation by the waveform selected.

Electric Head-Only Stunning of Lamb

EHOS refers to a pair of electrodes being placed on the lamb's head in such a way as to span the target organ – the brain. Current flows between the electrodes through the brain, stimulating it to induce a grand mal epileptic seizure (Grandin, 2010) in the animal which renders it unconscious. HSA (2004) describes best-practice in relation to electrical stunning of sheep in their guidance booklet. Since EHOS is a reversible process (Grandin, 2010) bleeding must follow within 15s to initiate the death of the animal before it can regain consciousness. An EHOS animal that is effectively stunned produces a tonic then clonic phase which are characterised as follows (HSA, 2004).

Tonic Phase (Animal Rigid)

- animal collapses and becomes rigid
- no rhythmic breathing
- head is raised
- forelegs extended and hind legs flexed into the body

Clonic Phase (Animal Kicking)

- gradual relaxation of muscles
- gradual return of rhythmic breathing
- paddling of involuntary kicking (can be quite severe)
- downward movement of the eyeballs
- urination and/or defecation

The recovery phase follows, if the animal is not bled, and is characterised by return of rhythmic breathing. The recommended current for lamb/sheep is 1 amp (PATK (2009), Gregory (2007)). Gregory (2007) further states 'It is recommended that the current should be applied for at least 3s, but this is not a validated standard.' PATK (2009) does not require an application time for EHOS of lamb.

EHOS is most effective when the epilepsy is induced before any pain is felt. It takes approximately 150ms for animals to process pain signals therefore an 'immediate' stun would be one that induces epilepsy within this time. Research in New Zealand (Cook, 1993) has demonstrated that epileptiform activity is generated in the brain through the over-stimulation of nerve endings by the stunning current. The 'over excitation' stimulates the release of two neurotransmitters (glutamate and aspartate) which at very high levels of production result in epileptiform activity in the brain. Research has demonstrated that passing a 1.0 amp current (50 Hz, 500V) for less than 0.2 s through the head of a sheep does not produce a seizure-like state as evidenced by the recorded electroencephalogram (Cook *et al*, 1995). Therefore, the production of epileptiform activity in the brain may not be immediate (<200 ms). However, the application of high amplitude alternating current (AC) to neural tissue will inhibit normal function for the duration of current application, thus bridging a possible gap between the start of current application and the initiation of epileptiform activity. The criterion for 'immediacy' is therefore assured.

Velarde *et al* (2002) assessed the return to consciousness after EHOS (250V constant V, 50Hz, 3s, dry scissor tongs) in 24 lambs. The average current received by the animals was 2.14 $\pm$ 0.47A and all lambs recovered consciousness. After EHOS, lambs went through a tonic phase (ending 10s after the stun), an initial clonic phase (ending 36s after the stun) and a second clonic phase (ending 70s after the stun). The initial and second clonic phases were defined after observations by the authors. They concluded that during the tonic and first clonic phase the animal was unconscious whereas during the second clonic phase there was some return of cortical function. Rhythmic breathing returned at about 29s post-stun and the corneal reflex at about 38s. They suggested that the return of

rhythmic breathing is the safest indicator that the animal is close to recovering consciousness.

IHIA (2010) provides guideline parameters for electrical stunning to be 0.6A for lamb and 0.6-1.0A for sheep; both applied for 1-3s.

Mis-stuns occur in practice and can happen when

- there is poor contact between the electrodes and the animal
- the stunning equipment does not provide enough current
- there is higher inherent resistance between the electrodes and the animal (e.g. due to extra wool, not being sufficiently wet, etc.)

Mis-stuns are painful for the animal and so have to be managed and minimised. Currently there is no reliable data showing the level of mis-stuns in UK lamb abattoirs but PATK (2009, Article 5) will require FBOs to perform checks on stunning to *'ensure that the animals do not present any signs of consciousness or sensibility in the period between the end of the stunning process and death'*.

Electrical Stunning Equipment

UK mains voltage and frequency is 220-240V sinusoidal AC at 50Hz. Stunning control units are highly variable and come with varying levels of functionality. Historically many stun-units were constant voltage by design which produces variation in current magnitude based on the resistance of the animal. In contrast modern units have internal current feedback control circuits to control the output current, frequency and duration. This provides better assurance for Halal purposes as one can limit the maximum current (and hence limit the field spread) as well as the duration of application. [Note: This does not apply to electrical water-bath stunning equipment for poultry which are unfortunately all constant voltage by design].

Some examples of electrical stun control units include the Freund E514 and the Karl Schermer CS-1. The Freund Stun-E514 is a constant current stunning box for sheep and cattle where frequencies can also be manually adjusted (www.freund-

germany.com/uploads/_downloads/Electric-Stunners%202009.pdf). The maximum programmable parameters are 400V, 2.5A and 1,330Hz. The Karl-Schermer CS-1 is also constant current but the range of frequencies and current outputs are relatively limited and must be changed by the manufacturer rather than the operator in the plant (www.karl-schermer.de/index.php?id=4&L=3&cHash=7c2b5e19ae).

Electrical Stun Handsets

Generally speaking there are three different types of electrical stun applicators – prongs, scissor tongs or forks. Prongs and tongs are the most popular depending on the method of animal restraint.

Prongs have fixed electrodes and are operated by one hand normally in the middle of a v-restrainer. The Jarvis model 2A head-to-back stunner (Figure 1) has electrical prongs at the front and an electrode at the back for simultaneous head and heart application. However, it has the flexibility to be rewired easily to convert it to a head-only stunning applicator. Furthermore it incorporates an internal water spray that helps to reduce resistance on contact with the lamb's head.

Scissor tongs (Figure 2) require a two-hand operation but have the flexibility of being able to adjust to different head sizes. They can be used with any restraining device (v-restrainer, cradle, table etc.) and are routinely used when stunning animals free-standing in stunning pens. Forks (Figure 3) are operated using one hand at the exit of a v-restrainer. The electrodes are fixed and spiked. It must be delivered with force to facilitate a good contact.

Figure 1: Jarvis Model 2A Head-to-Back Stunner
(prongs at the front and electrode at the back)
(www.jarvisengineering.com/model2a.shtml).
For use with a v-restrainer.

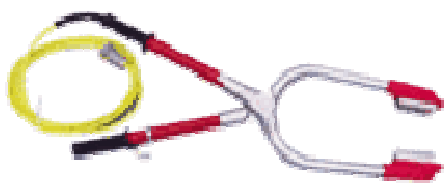

Figure 2: Stunning Tongs
(Product name Stunning tongs type Z3)
(www.karl-schermer.de/index.php?id=3&L=3)
For use in a stun-pen or any restraining device.

Figure 3: Stunning Forks
(Product name Stun-Tong-EF for pigs but is also used for sheep)
www.freund-germany.com/show-product.php?typ=STUN-TONG-EF).
For use with a v-restrainer.

Animal Orientation at Slaughter and Restraint

Effective orientation of the animal at slaughter is important. It facilitates easy operational handling and flow, provides access to the neck for slaughter, enables efficient blood loss at exsanguination and improves welfare. Some or all of these may be competing priorities. The 'right' orientation depends on the priorities of the slaughter system objectives, the equipment deployed and the competence of the operators. The 4 main orientations of sheep at slaughter are

- upright (e.g. free-standing),
- lateral recumbancy (e.g. prone on its side on the ground),
- dorsal recumbancy (e.g. on its back in a cradle/table after EHOS) or
- vertical (e.g. hanging on the line after EHOS).

It is important to restrain the animal properly to facilitate a correct stun or cut. Generally sheep are restrained by either a v-restrainer (a type of restraining conveyor), stunning pen, small-scale double-rail restraint, cradle, table or manually held on the ground.

V-restrainers (Figure 4) are used extensively in New Zealand as the optimal method of restraining variable sizes of sheep in high-throughput abattoirs. Sheep are held comfortably by two moving conveyors in the shape of a V. Once restrained, they tend not to struggle except where they see an open space at the end of the conveyor (Gregory, 2007). Temple Grandin developed a similar restrainer-conveyor (Figure 5) where sheep

are restrained and supported under the brisket and belly. Dr Grandin's restrainer may not be so easy to adopt in the UK where the number, variety and sizes of sheep makes the selection of an appropriate size of brisket conveyor a challenge.

A sheep stunning pen is simply a pen where the stun-unit, applicator and hoist equipment are situated. Batches of sheep are moved into the pen and the operator uses stunning tongs to head-only stun them. Another operator shackles the stunned animal and puts it onto the hoist where the animal gets elevated onto the slaughter line ready to be bled by the slaughterman. This method of restraint is successful when there are reasonable numbers of sheep in the room but as the numbers decrease the remaining animals can get stressed and are harder to stun correctly.

A small scale double-rail restraint device (Figure 6) was developed by Spirit of Humane (http://spiritofhumane.com) as a low-cost way to restrain animals in an upright position.

Cradles (Figure 7) are used extensively for on-farm sheep management purposes (foot trimming and general inspection duties). Sheep are backed up to the cradle and flipped over a rollover bar to restrain them on their back. Abattoirs may use a number of cradles depending on production speed requirements.

'Table' restraint generally refers to any restraint method where sheep are manually held (usually by 1 or 2 men) to facilitate stunning and/or slaughter. It may actually be on a table or a block or it could just be prone on the floor. Sometimes, especially in the developing world, sheep's legs are tied so they lie prone on the floor unable to move. Sheep can also be restrained by being shackled live by one leg but PATK (2009) outlaws this method of restraint in Europe as it causes unnecessary stress to the animal.

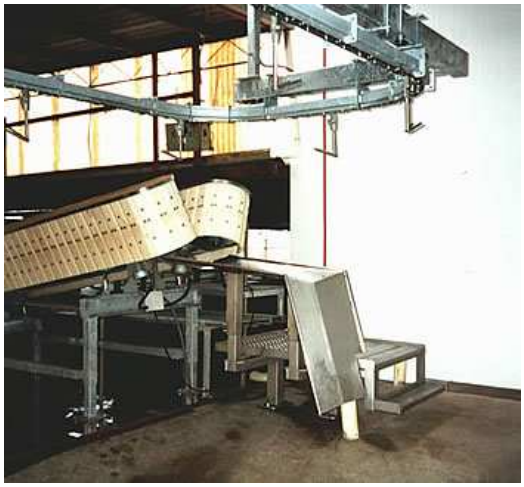

Figure 4: Sheep V-Restrainer
(www.adluk.net/machines/restrainer.aspx)

Figure 5: Sheep Double-rail Restrainer-Conveyor
(www.grandin.com/restrain/new.conv.rest.html)

Figure 6: Sheep Double-rail Restraint for Small Scale Premises
(http://spiritofhumane.com/order)

Figure 7: Sheep Cradle Designed for Farm Use
Similar designed cradles are used in abattoirs.
(www.acorndev.co.uk/id25.html).

Abbreviations

CBS	Captive-bolt Stun
CL	Cook Loss (of meat pre- and post-cooking)
DL	Drip Loss (of carcass or meat over a period of time)
EHOS	Electric Head-Only Stun
EHBS	Electric Head-to-Back Stun
FBO	Food Business Operator
GS	Gas Stun
GM	Genetically Modified
KO%	Killing-Out Percentage
LD	Longissimus Dorsi (longest muscle found in the back of animal)
LW	Live-Weight
NCBS	Non-Penetrative Captive-bolt Stun
NS	Non-Stun
NSGC	Non-Stun Gash Cut (as traditionally practiced in New Zealand)
NSND	Non-Stun Neuromuscular Blocking Drug
PCBS	Penetrative Captive-bolt Stun
PCEHOS	Post-Cut Electric Head-only Stun
PCV	Packed Cell Volume
SF	Shear Force (to measure tenderness)
WHC	Water Holding Capacity (ability of meat to retain moisture)

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