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Ecchymosis
What Causes It?

A report for the Rural Industries Research and Development Corporation

By Robert C Mulley and David F Falepau
University of Western Sydney, Hawkesbury

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Researcher Contact Details
Dr Robert C Mulley
Dean
Faculty of Environmental Management & Agriculture
University of Western Sydney - Hawkesbury
RICHMOND NSW 2753

Phone: 02 4570 1438
Fax: 02 4570 1383
Email: r.mulley@uws.edu.au
Website: http://www.hawkesbury.uws.edu.au

RIRDC Contact Details
Rural Industries Research and Development Corporation
Level 1, AMA House
42 Macquarie Street
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6272 4539
Fax: 02 6272 5877
Email: rirdc@netinfo.com.au
Website: http://www.rirdc.gov.au

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Foreword

Ecchymosis – or blood splash as it is commonly known – results in carcasses being downgraded or condemned. It produces industry losses that no one in the industry can afford.

This study seeks to identify the factors which cause ecchymosis. The report proposes a set of slaughter procedures to suit the particular slaughter systems. A set of recommendations are also included for industry consideration.

This report, the latest addition to our diverse range of nearly 300 research publications, forms part of our deer R&D program which aims to foster the deer industry as a profitable and efficient mainstream enterprise option for Australian agriculture.

Most of these publications are available for viewing, downloading or purchasing online through our website at www.rirdc.gov.au/pub/cat/contents.html

Peter Core
Managing Director
Rural Industries Research and Development Corporation

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Mr Colin Ward and Mr and Mrs Ian Mons obligingly supplied deer of particular specifications at much discounted prices, and Mr Bill Miles also supplied deer at negligible cost.

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Finally, we will forever be indebted to the hundreds of fallow deer that contributed to the study.

Contents

Executive Summary

This report describes experimental work conducted to define factors associated with the occurrence of ecchymosis (blood splash) in fallow deer. Data were collected on 1804 deer slaughtered experimentally (*n*= 494) or at commercial works (*n*= 1310) in a range of different slaughter systems.

There were a number of different slaughter systems available for the slaughter of deer in Australia. Three types of slaughter system were used for fallow deer only, typified by the types A, B, and E abattoirs described in this study. One type of slaughter system slaughtered fallow deer and red deer (Type D), and another (Type C) red deer or rusa deer only.

The major differences between these slaughter systems were whether they were purpose built for animals of only one particular size, their capacity to achieve a short (< 5 seconds), medium (< 10 seconds), or long (> 10 seconds) interval between stunning and the initiation of exsanguination, and their capacity to implement various stunning and exsanguination methods. From the results of the current study it was concluded that ecchymosis at each of these abattoir types could be reduced, but only if recommendations specific for each type were adopted.

At type B abattoirs, where the interval between stunning and the initiation of exsanguination was < 5 seconds, thoracic stick exsanguination significantly ($p < 0.001$) reduced the incidence of ecchymosis combined with electrical stunning, and it is possible that captive bolt stunning would reduce this further. However, because of the success of the thoracic stick method in reducing ecchymosis in this slaughter system considerable numbers of animals would be required to discern a difference between these methods of stunning.

Type E abattoirs were purpose built for slaughtering deer the size of fallow deer and could achieve intervals between stunning and the initiation of exsanguination of less than 10 seconds but never as short as 5 seconds. These abattoirs experienced little ecchymosis using captive bolt stunning combined with the thoracic stick method of exsanguination. At type E abattoirs electrical stunning was not possible due to the design of the restraint device.

At type D abattoirs, where the minimum interval possible between stunning and the initiation of exsanguination was approximately 15 seconds electrical stunning reduced the amount of ecchymosis in groups of deer whether exsanguinated by the thoracic stick or gash cut methods ($p < 0.05$) in comparison with captive bolt stunning. Importantly, while electrical stunning was shown to reduce ecchymosis in comparison with captive bolt stunning in type D abattoirs, in slaughter systems employing electrical stunning, exsanguination **must** be initiated within 20 seconds of stunning to ensure that death supervenes due to the loss of blood, prior to the animal regaining sensibility. Observations from the current study suggested that this might have been difficult to achieve in some type D abattoirs due to the design of the devices used for restraining deer.

Reducing the interval between stunning and the initiation of exsanguination from 25 seconds to less than 10 seconds significantly reduced the amount of ecchymosis regardless of stunning method ($p < 0.008$), highlighting the importance of this factor.

Case studies of deer slaughtered at different abattoirs to determine the prevalence of ecchymosis were conducted. Of 963 fallow deer slaughtered at abattoir types A, B and D, 23.1 % had ecchymosis $\geq$ grade 1, and 8.2 % had ecchymosis $\geq$ grade 2 in the left round, which was shown in the current study to be indicative of ecchymosis in the loins and/or other hind leg primals. No ecchymosis was detected in the loins or hind leg primals of 50 fallow deer slaughtered at a type E abattoir. Of 257 rusa deer slaughtered at a type C abattoir, 14.8 % had ecchymosis $\geq$ grade 3 in the loins. Of 94 red deer slaughtered at a type D abattoir, only 1 had ecchymosis $\geq$ grade 2 in the round.

It is important to note that these data take no account of differences between slaughter systems, sex of animal, or method of slaughter. Although red deer did not appear to get ecchymosis as often as fallow deer, this was probably because all red deer in Australia and New Zealand are stunned using a penetrative or mushroom head captive bolt stunner.

Head only electrical stunning was examined in detail because of the compatibility of this method with the requirements of Muslim consumers in both domestic and export markets. Experiments involving mixed age fallow deer bucks, does and castrates revealed that this species should be stunned using a minimum of 150 volts (50 Hz) for 1-3 seconds. Lower voltages of 70 - 100 volts, which were used in some commercial abattoirs, was unacceptable on animal welfare grounds as animals could not be guaranteed to be rendered insensible, and could only be exsanguinated after stunning at these low voltages, where sufficient restraint was available to physically immobilise the animal. Neither voltage nor duration of electrical stunning affected the interval to cessation of heartbeat (mean = 113.8 seconds after stunning), which was a major consideration guiding Muslim slaughter techniques. Since stun voltage had no effect on duration of heartbeat, down regulation of the voltage applied by Muslim slaughtermen in commercial works should be discouraged.

The method of exsanguination was shown to be a critical factor in the development of ecchymosis. The rate of blood loss using the thoracic stick method was significantly ($p < 0.001$) greater than the gash cut method regardless of stunning method and there was also a significant ($p < 0.05$) stunning by exsanguination method interaction, with electrical stunning associated with a greater rate of blood loss in thoracic stuck deer, in contrast with the captive bolt being associated with the greater rate in gash cut deer.

The thoracic stick method of exsanguination incorporated into slaughter systems (type B) where the interval between stunning and exsanguination was < 5 seconds significantly ($p < 0.001$) reduced the amount of ecchymosis even when following electrical stunning. The same effect was observed in slaughter systems where the interval between stunning and exsanguination was > 5 seconds but not to the same level of significance ($p < 0.03$).

Restricting the movement of the animal subsequent to the onset of the grand mal seizure induced by the stun was tested, and it was concluded that mechanically limiting the cranial extension of a hind limb to less than its maximum potential reduced the incidence of ecchymosis in the round (*M. vastus lateralis* and *M. rectus femoris*) and a number of other muscles. It may be possible to design a restraining device that restricts muscle contraction, however it should be noted that any restraint on the animal prior to stunning may compromise it's welfare.

The effect of sex type on the expression of ecchymosis was observed in a number of experiments. Castrates were 9.8 times more likely to have ecchymosis than bucks (p= 0.002), and does 4.2 times more likely (p= 0.06). Even during the breeding season bucks were more likely to have bruising and lesions from traumatic injury, and high ultimate carcass pH from muscular exertion, rather than ecchymosis resulting from slaughter. The susceptibility of castrates to ecchymosis is difficult to explain, but may be associated with stressors, which lead to a 'fear' reaction, as distinct from stressors manifest in physical effects on muscles. Circulating steroid hormone (testosterone, progesterone, cortisol) levels were measured for fallow deer (*n*= 231) slaughtered in this study, but were not shown to affect the expression of ecchymosis.

Fallow deer carcasses (*n*= 8) affected with ecchymosis were dissected to determine the extent of distribution of lesions. Of the 752 hindquarter muscles inspected 217 (29 %) exhibited ecchymosis while only 38 (0.05 %) of the 800 forequarter muscles inspected were affected. The most frequently affected muscles were also those which sell at retail for the highest price per kilogram. For the hindquarter these were the *M. longissimus dorsi, M. vastus lateralis, M. rectus femoris, M. semimembranosus, M. adductor femoris, M. biceps femoris, M. semitendinosus,* and *M. gluteus medius*, and for the forequarter they were the *M. supraspinatus* and *M. infraspinatus.* The results of the current study also showed that the presence of ecchymosis in the diaphragm or abdominal muscles, and in visceral organs such as the lung and heart, was an unreliable indicator of the presence of ecchymosis in other parts of the carcass.

Importantly the denvering process (often referred to as denuding), which involved the removal of inter-muscular fat and selvage surrounding a particular muscle or group of muscles which comprised a commercial cut, was observed to remove almost all visible ecchymotic lesions when those of only grade 1 or 2 severity were exhibited. Accordingly meat should not be inspected for ecchymosis until after the denvering process.

Testing of microbiological markers (*Pseudomonas spp.* and *Lactobacillus spp.*) for meat keeping quality indicated that venison affected with ecchymosis did not deteriorate more quickly than venison without ecchymosis, for up to 4 weeks of storage post slaughter.

This study has shown that a number of factors contribute to the expression of ecchymosis in the carcasses of slaughtered deer, and the tailoring of slaughter procedures to suit particular slaughter systems is likely to reduce the extent to which ecchymosis occurs. The Australian deer industry has a number of alternative slaughter systems available for the slaughter of fallow deer and with this there is a unique opportunity to utilise those shown to be more compatible with the requirements for reducing ecchymosis in fallow deer, to gain a competitive edge in the international and domestic market for quality fallow deer venison.

1. Introduction

Quality assurance is an important component of modern meat production systems, and this is especially true of the Australian Meat industry, which relies heavily on quality of product for meat exports. In 1994 it was recognised that ecchymosis, which was being seen often in the carcasses of slaughtered deer, was a meat quality defect that may affect the saleability of venison, since approximately 85% of venison produced in Australia is sold to export. Anecdotal reports from abattoirs and boning rooms suggested that up to 20% of fallow deer slaughtered, and to a lesser extent red deer, had some degree of ecchymosis, with 100% of animals affected in some kills. Previous studies on the occurrence of ecchymosis in sheep, cattle and pigs indicate that these haemorrhagic lesions appear to be associated with slaughter technique, although predisposing factors such as pre-slaughter stress of animals due to transportation or lairage were also implicated in some studies.

This study examines slaughter systems used for deer in Australia and describes aspects of these thought to relate to the occurrence of ecchymosis. Relationships between the occurrence of ecchymosis and factors such as pre-slaughter management and stress, methods of stunning, the temporal relationship between stunning and exsanguination, and combinations of these factors were assessed. Recommendations to industry that will minimise the extent to which ecchymosis occurs in slaughtered deer were devised as a result of this study.

1.1 What is ecchymosis?

There are two different haemorraghic syndromes associated with the slaughter of animals (Petersen *et. al.*, 1986). Blood splash, which is referred to as ecchymosis throughout this study, is associated with head only methods of stunning, and speckle is more frequently associated with head to body electrical stunning (Gilbert & Devine, 1982). Ecchymosis of varying degrees, exhibited in venison Rounds and loins, is described in the ecchymosis grading chart produced in stage 1 of the project (Tuckwell & Hubbard, 1996).

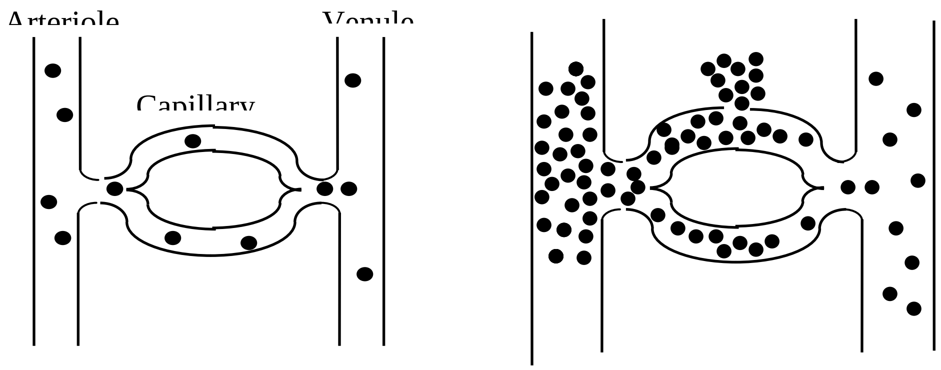
Ecchymosis appears as small dark spots on the surface of various muscles of a carcass and some organs. In severe cases ecchymosis may extend deep into the muscle. The spots seen on the surface of skeletal muscles range from 1mm to 1cm in diameter and are considered distinct from larger hemorrhages or bruising caused by external injury, and blood which has leaked from larger blood vessels external to the muscle tissue. The condition ecchymosis is usually characterised by a number of small lesions broadly distributed across the carcass, whereas bruising is usually comprised of larger lesions, localised, and clearly associated with localised trauma. Light and electron microscope images of ecchymotic lesions in lamb carcasses have shown them to be due to the localized discharge of blood from ruptured muscle blood vessels into the surrounding muscle tissue. These images also showed the ruptured blood vessels lying adjacent to super-contracted muscle fibers (Leet *et. al.*, 1977)

Speckle, as described by Gilbert & Devine (1982), is caused by the rupture of blood vessels in the subcutaneous fatty tissue and connective tissue overlying the muscle. It is characterized by multiple discrete petechial haemorraghes and has the appearance of a rash (Petersen *et. al.*, 1986). Speckle is of no commercial significance, and is not further considered in this study.

The rupture of muscle blood vessels

Thornton & Gracey (1974) put forward the following diagrammatic representation and posited that ecchymosis, resulting from blood leaking out of ruptured capillaries, was caused by the flooding of capillaries as a result of vaso-dilation of arterioles following vaso-constriction stimulated by muscular contractions associated with electrical stunning (Figure 1).

Figure 1.1: Engorgement and rupture of capillaries.



Vaso-constriction which occurs during application of current

Vaso-dilatation which occurs when electrical stimulus

Thornton & Gracey (1974) *Meat Hygiene, 6th Ed.*, Balliere Tindall, London, p52.

1.2 The slaughter process

Although maintaining the proposition that ecchymosis was caused by both the contraction of muscle fibers and changes in the vascular system, Gregory (1987) suggested that the rupture of blood vessels was more likely to occur if aneurysms caused by the super-contraction of muscle fibers occurred simultaneously with an increase in systolic pressure.

Animal slaughter involves immobilisation of animals by stunning (electric, captive bolt, CO_2) to induce immediate and continued insensibility during exsanguination, resulting in death by anoxia (Lawrie, 1991). Apart from a rapid and humane death, the removal of blood from the carcass is important to ensure adequate eating and keeping qualities of meat (Lawrie, 1991). The bleeding process in cattle and sheep is usually effected by severing the jugular vein and the carotid artery, and in pigs by severing the vena cava (Blackmore and Newhook, 1976; Lawrie, 1991). The traditional sticking or exsanguination method for sheep slaughter was the transverse neck cutting method which is sued in the Halal exsanguination of fallow deer in Australia (Falepau and Mulley, 1998) and New Zealand (Cook *et. al.*. 1994b). This transverse method severs the trachea, oesophagus, common carotid arteries and jugular veins, and the spinal cord at the occipito-atlantal junction (Blackmore and Newhook, 1976).

The introduction of pre-slaughter stunning by the meat industry was to aid in immobilising animals, which improved the safety and efficiency of the slaughter and dressing procedure (Gilbert, 1993). Consideration of hygiene, and animal welfare concerns related to traditional slaughter techniques gave rise to legislature to enforce this operation; like the Slaughter of Animals Act in the United Kingdom in 1933, and mandatory stunning of sheep in New Zealand after October 1977 (Warrington, 1974; Blackmore, 1979).

Stunning methods used may depend on the species slaughtered, legislature, or a religious requirement (Lawrie, 1991). Percussive stunning comprises captive bolt and non-penetrative percussion stunning which renders the animal unconscious by a concussive blow (Blackmore, 1979) and is predominantly used for cattle, calves, sheep and deer (Lawrie, 1991). Electrical stunning, has been used in a variety of species including sheep, deer, pigs, chickens and fish (Cook *et. al.*. 1994a), and carbon dioxide narcosis has also been used in pig slaughter systems (Forslid, 1988; and Barfod and Madsen, 1988).

Halal slaughter traditionally did not include the immobilisation step, but head-only electrical stunning or Halal stunning (HS), is now required in New Zealand and Australia (Gilbert, 1993; Falepau and Mulley, 1998), but is a low voltage reversible stun. Gilbert (1993) outlined the basis Halal requirements to ensure that the slaughter is humane and still complies with Halal laws.

Electrical stunning was legally introduced in the UK in the 1930;s and since this time an increase in haemorrhage formation has been evident (Warrington, 1974). Although percussion, cash-pistol and captive bolt methods can lead to the production of this meat blemish in sheep, a greater frequency is displayed when electrical stunning is employed (Blackmore, 1979; and Kirton *et. al.*. 1981b). However, this general finding is not always consistent because Burson *et. al.*. (1983) reported more blood splash in pigs that were captive bolt stunned compared with those electrically stunned. This inconsistency may be due to a delayed time between stunning and exsanguination, the voltage setting, or perhaps a species difference (Wotton *et. al.*. 1992). All of these variables have been shown to influence the production of ecchymosis and reveals further the complex interaction of factors that may lead to this phenomenon.

1.3 Electrical stunning and haemorrhage

A focus on electrical stunning with regard to blood splash formation is more relevant, as both the Australian and International deer industries have reported substantial losses via product rejection due to ecchymosis. An assortment of electrical stunning procedures and accompanying exsanguination techniques have been investigated in a variety of species and have provided important clues in the etiology of ecchymosis.

The major variations in electrical stunning parameters and procedures investigated to potentially manipulate occurrence of muscle haemorrhage defects are listed below. A review of the history and research on electrical stunning of animals, pre-1974, was prepared by Warrington (1974).

a) Modulating voltage delivered
b) Change the frequency (Hz)
c) Stunning duration
d) Location of electrodes
e) Duration between stun and exsanguination

Haemorrhage due to voltage setting has been reported, but the results are inconsistent, and may be due to other intervening factors in these studies. For example, both Burson *et. al.*. (1983) and Lambooy and Sybesma (1988) reported a reduction in haemorrhage after stunning pigs at higher voltages, 540V and 475V respectively, compared with the normal voltage setting of 70V. In contrast, Lambooij (1994) found that a lower stunning voltage was adequate in reducing ecchymosis in pigs, and Krana *et. al.*. (1996), looked at electrically stunning chickens and found more muscle haemorrhage in animals that were whole body stunned at 100V (50Hz, 4s) compared with head only stunned at 25V (200Hz, 4s). The discrepancies here may be related to the restraining method employed, the stunning technique and perhaps reflect species differences. Lambooy and Sybesma (1988) identified that V-type restraint caused more muscle haemorrhage compared with both free standing and band restrained stunned pigs. This is reflected in rats and sheep stunned while in a V-type restrainer (Leet *et. al.*. 1977; Gilbert and Devine, 1982).

High frequency stunning, ranging from 1300Hz to 2250Hz, has been used in a number of studies and, in contrast to conventional frequency levels (50Hz), has resulted in the reduction of muscle haemorrhages (refer to review by Warrington, 1974). A more recent publication by Daly and Simmons (1994) also reported reductions in bone breakages and blood splash in pigs stunned at 1500Hz. Further, Daly and Simmons (1994) proposed that the mechanism behind high frequency reductions in ecchymosis was related to repolarisation rates of nerve and muscle cells. Nerve or muscle cells are depolarised by each inversion of the stimulation voltage. The rate of depolarisation increases as frequency rises to around 1000Hz, where the cells can not repolarise sufficiently fast. When the nerve cells can not repolarise quickly, the cells ‘miss a beat’ and the number of cells depolarising at a given time is proposed to decrease, corresponding to a reduction in muscle contractions and ruptured blood vessels.

With reference to stunning duration, Lambooy and Sybesma (1988) found that more haemorrhages were found in the shoulders of pigs, the longer the stun was applied. The stun duration was thought to determine the haemorrhage outcome rather than the voltage setting, although the stun and voltage times were inconsistent, making comparison difficult (ie 50 pigs stunned at 70V for 10s and 50 pigs stunned at 475V for 3s). Lambs electrically stunned with higher current and for greater than 10s stunning duration were found to have more ‘speckle’ or petechial haemorrhage (Devine *et. al.*. 1983).

Studies that have investigated the location of electrodes during the stunning process have been the most valuable in changing haemorrhage distribution and, in combination with vasoactive drugs, have provided critical clues in the physiological processes that may forge conditions that lead to ecchymosis.

The main criteria for the success of an electrical stun is the onset of a grand mal seizure (Warrington, 1974), which is characterised by a number of visual cues including:

1. the tonic phase, indicated by the violent stretching of the hind and forelegs, the arcing of the neck and backward movement of the head, and the cessation of respiration;

2. the clonic phase, which supervenes approximately 10 seconds after stunning, and is indicated by the relaxing of the muscles and paddling movements of the legs; and
3. if the animal is not exsanguinated, the regaining of consciousness, which occurs approximately 60 seconds after stunning and is indicated first by a return of the pupillary reflex to light, then a return of muscular coordination after a further 30 seconds (Grandin, 1983).

1.4 Exsanguination of livestock

As with stunning methods, there were also a number of alternative methods of exsanguination implemented in slaughter systems throughout the world. The choice of method was determined by a number of factors including; ritual slaughter requirements, species of livestock, and the presentation of the animal for exsanguination. The only method of exsanguination accepted by the appropriate authorities for kosher or Muslim slaughter was the gash cut method involving the severance of all the major blood vessels of the neck. In New Zealand and Australia either the gash cut method for ritual slaughter, or a permutation of it which did not sever the oesophagus called the spear stick method (Blackmore & Newhook, 1976) for non-ritual slaughter, became the only methods used on sheep. With cattle two methods of exsanguination were used; the gash cut method for ritual slaughter whether stunned prior to exsanguination or not, and sometimes after hoisting without stunning (Grandin, 1983), and the thoracic stick method also referred to as chest sticking (Anil *et. al.,* 1995), used commonly in non-ritual slaughter involving the severance of the major blood vessels of the thoracic cavity and usually conducted after hoisting. Religious beliefs precluded the consumption of pork by kosher consumers and Muslims and the thoracic stick method of exsanguination became the common method used for the slaughter of pigs.

1.5 Research on ecchymosis

From the available literature it is apparent that a number of factors affect the incidence of ecchymosis including; the means of stunning, the means of exsanguination, and the length of the interval between stunning and exsanguination, and these factors differ considerably between the slaughter systems employed for the various species of livestock concerned. Research on ecchymosis, some of which is cited above, appeared to occur in different species at different times, often as changes to slaughter systems were introduced and ecchymosis became more, or less, prevalent. For this reason, research on ecchymosis in cattle, pigs, sheep, and deer will be reviewed separately.

Cattle

Cattle slaughter systems in use in Australian abattoirs generally comprised a race leading from the holding yards into a pen in which the movement of the beast was restricted enough to facilitate stunning, otherwise known as a knocking box. The side of the knocking box was able to be opened to allow the beast to be removed and hoisted, or alternatively in some systems the floor dropped out. Cattle were originally stunned by being struck on the head with a poleaxe, and later, with either a firearm or captive bolt. In 1960, Charles (1960) reported observations made over the six years prior on ecchymosis in cattle in Queensland, Australia. In that study the Queensland Department of Primary Industries had recorded 30 cases of ecchymosis out of 114,000 cattle slaughtered at one works over two seasons, and two cases out of 72,000 cattle slaughtered at another. The worst incidence was at a far west Queensland abattoir where 71 cases out of 1417 cattle slaughtered were recorded. At a smaller abattoir which slaughtered approximately 700 cattle per day incidences of 5 - 10 % were common (Charles, 1960).

Charles (1960) also reviewed the work of others (Thornton, 1949, Anthony, 1951, Collins; 1954; cited in Charles 1960) and postulated that ecchymosis was brought about by physical and mental stress applied to a susceptible animal at the time of slaughter and could be induced by:
1) increase in blood pressure;

2) muscular contractions at the time when blood pressure is raised; and
3) delay in relief of blood pressure, i.e. exsanguination (Charles, 1960).

Charles (1960) also put forward that the effect of the above factors was further dependent on individual animal variations including; temperament, condition and possibly sex. Regarding sex, Charles (1960) observed that ecchymosis was mainly seen in ox carcasses but very seldom in the carcasses of cows. Supporting the proposition that pre-slaughter condition in some way predisposed cattle to ecchymosis, Charles (1960) also cited Monlux and Mason (1959) who posited that haemorrhages in beef were caused by excessive muscular exertion together with a deficiency of a substance such as Vitamin E or selenium that regulates the metabolism of muscle. Charles (1960) also observed that in the majority of cases in cattle, ecchymosis was confined to the muscles of the forequarter and only in extreme cases did ecchymosis occur throughout the entire carcass.

Perhaps because of the low prevalence of ecchymosis in cattle carcasses, little research on ecchymosis in cattle has since been conducted. Daly & Simmons (1994) (MIRINZ, undated) in a review discussing high frequency stunning of livestock, put forward that in cattle, when coupled with the thoracic stick method of exsanguination, high frequency stunning appeared to abolish ecchymosis altogether. However, if the gash cut method was used ecchymosis was still a problem. Smulders *et. al.* (1989) investigated the effect of electrical stimulation and shackling by either the left or right leg, on the incidence and severity of ecchymosis in veal calves and found that neither electrical stimulation nor the side shackled had any effect. The interval between stunning and exsanguination was not reported but electrical stimulation was said to commence 1 minute after the initiation of exsanguination. Even with the introduction of electrical stunning of cattle, which was associated with the highest incidence of ecchymosis in sheep (Kirton *et. al.*, 1980-81b), in slaughter systems comprising head restraint systems in some large abattoirs, described in Grandin (1983), there appeared to be no resurgence of research into ecchymosis in cattle. After 1960, apart from the reported by Smulders *et. al.* (1989) and Daly & Simmons (1994) (MIRINZ, undated), ecchymosis in cattle was generally only referred to as an occasional meat quality defect in reviews or technical publications concerning meat quality or slaughter methods in general (Gilbert, 1993; Grandin, 1983; Warrington, R., 1974).

Pigs

The use of stunning prior to the exsanguination of pigs was initially required in order to carry out the exsanguination procedure. Then, as more mechanised slaughter systems were developed and concern over the welfare of animals increased stunning was gradually implemented in most countries. Slaughter systems for pigs now vary from those used in smaller abattoirs where the pigs are stunned free standing in a small pen, to mechanized systems which use conveyers similar to those used for sheep and cattle in large abattoirs. Pork is not consumed by either kosher consumers or Muslims and could therefore be stunned by any method including those which cause cardiac arrest, and pigs are generally always exsanguinated using the thoracic stick technique.

As an indication of the prevalence of ecchymosis in pigs, an incidence of 82.5%, with 2.5 % being of commercial significance, was reported in a trial investigating the effect of head to back electrical stunning (Wotton *et. al.*, 1992). The authors suggested this to be consistent with incidences of ecchymosis in groups of pigs which were head only electrically stunned commercially.

Some research has been conducted on the slaughter of pigs and its effect on the incidence of ecchymosis. Lambooy & Sybesma (1988) investigated a number of variables associated with pre-slaughter handling, stunning and exsanguination of pigs. They compared; stunning at 475 volts for 3 seconds and stunning at 70 volts for 10 seconds, transport prior to slaughter and no-transport prior to slaughter, free standing at stunning and restraint in a v-restrainer and, chemical and electrical stunning. Low voltage, transport prior to slaughter, v-restraint and electrical stunning were all associated with a higher incidence of ecchymosis in the shoulders of pigs than their corresponding treatments. The interval between stunning and exsanguination varied between experiments ranging from 10 to 25 seconds.

Burson *et. al.* (1983) investigated factors associated with slaughter methods comparing the effect of captive bolt and electrical stunning, and the interval between either of these methods and exsanguination, on ecchymosis in barrows (castrate) and gilts. Sex type showed no association with ecchymosis. Captive bolt stunning caused more ecchymosis if coupled with delayed exsanguination, than electrical stunning and captive bolt with a short interval between stunning and exsanguination, or electrical stunning with a delayed exsanguination. The interval between stunning and exsanguination varied between experiments, ranging from 18 seconds being the short duration and 144 seconds the delayed, in one experiment, and 9 and 100 seconds respectively in another. Bloomquist (1958) and van de Wal (1978), cited in Burson *et. al.* (1983), in similar experiments both found ecchymosis to be greater with delayed exsanguination in both electrical stunning and captive bolt. However lower stunning voltages were used.

Burson *et. al.* (1983) also extended the studies by Bloomquist (1958) and van de Wal (1978), cited by Burson *et. al.* (1983), to look at the anatomical distribution of ecchymosis. They found that ecchymosis was similar in carcass distribution and severity in both electrically stunned groups and the captive bolt group with short stun stick time. The captive bolt group with the delayed stun stick time however exhibited a greater prevalence of ecchymosis in the rump (*M. gluteus medius*). Burson *et. al.* (1983) also determined the diaphragm to be a good indicator of the presence of ecchymosis in other muscles of the pig carcass.

Calkins *et. al.* (1981) investigated a number of factors associated the slaughter of pigs and found a higher incidence of ecchymosis in the hams of hogs driven to slaughter by an electric prod compared to those driven with a leather strap. They did not find ecchymosis incidence to be related to either lean quality, average backfat thickness, muscling, sex, or weight. Calkins *et. al.* (1981) also compared various intervals between stunning and exsanguination including 15, 45, 75, and 105 seconds and found that although not significant, the lower interval appeared to be associated with a lesser incidence of ecchymosis. Stunning was at 220 volts for 2 seconds, which corresponded to 3 to 5 amps. It was not stipulated whether or not the head only or head to body method was used. Wotton *et. al.* (1992) investigated the placement of the rear electrode, in the head to back electrical stunning of pigs, and found no association between the location of the electrode placement and the incidence of ecchymosis. Daly & Simmons (1994) (MIRINZ undated), showed that high frequency stunning of pigs reduced muscular contractions and as a result caused less ecchymosis than conventional 50 Hz stunning.

Sheep

Most of the work investigating ecchymosis in sheep appears to have been conducted in New Zealand when ecchymosis in the carcasses of lambs became of concern following the compulsory introduction of pre-slaughter stunning in the late 1970's (Frazerhurst, 1976). While none of the published literature from New Zealand indicated the commercial incidence of ecchymosis in lambs, Restall (1980-81) from the United Kingdom cited incidences of ecchymosis in carcasses from one commercial slaughterhouse of 10%. However, as occurred in cattle in which the commercial significance was minimal, research did not appear to extend for much more than a decade. Just as the work in cattle and pigs considered factors peculiar to the slaughter systems employed for those species of livestock, work investigating ecchymosis in sheep appeared to focus on potential adaptations to the commercial slaughter systems already in place. Those slaughter systems comprised conveyer restraint systems capable of presenting over 500 animals an hour to the slaughterman. In contrast to the work on ecchymosis in cattle and pigs, where intervals between stunning and exsanguination were greater than 15 seconds and as much as 144 seconds, the work in sheep generally involved intervals of less than 5 seconds except in one case where an interval of 8 seconds was part of the experimental design. The use of the gash cut or spear stick method of exsanguination remained unchanged in the commercial slaughter systems and was therefore also the method used in most experiments investigating ecchymosis.

A number of workers investigated the effect of stunning method on ecchymosis in lambs, and all found the least incidence to be associated with captive bolt or percussion stunning in comparison to head only or high frequency (130 V, 1500 Hz) electrical stunning (Clark & Tweed, 1932; Spencer, 1979; Kirton *et. al.,* 1980-81b). This difference between stunning methods was originally suggested to be as a result of electrical stunning causing a greater rise in blood pressure than captive bolt stunning (Clark & Tweed, 1932). However, Kirton *et. al.* (1978) dispensed with this theory by showing that systolic blood pressure rises caused by head only electrical and captive bolt stunning were the same, thereby suggesting that it was the maintenance of elevated blood pressure rather than the level of elevation itself, that was the causal factor. Percussion stunning was also shown to further reduce the incidence of ecchymosis compared with captive bolt stunning, however the severity of the ecchymosis associated with either of these two method was never commercially significant (Kirton *et. al.,* 1980-81b).

Kirton *et. al.* (1980-81a) compared head only with head to back electrical stunning and found that the head to back stunning greatly reduced the incidence of ecchymosis in lambs. The heart stopping action of the head to back method and the consequent non-elevation of arterial blood pressure, was postulated to be the reason behind this occurrence. Petersen *et. al.* (1986) and Gilbert & Devine (1982) reinforced this proposition by measuring blood pressure changes associated with head only and head to back stunning. Head only stunning caused a two to three fold increase in arterial pressure but only a moderate increase in venous pressure, in contrast to head to back stunning which caused a decrease in arterial pressure and a more than moderate and constant increase in venous blood. In relation to this, Petersen *et. al.* (1986) also measured muscular activity using an electromyograph, and showed it to be greater for head to back than head only stunning, which suggested that the more constant increase in venous pressure seen in the head to back stunned lambs was associated with the vaso-constriction of the muscle blood vessels caused by more widespread muscular contractions.

Kirton & Frazerhurst (1983) investigated the proposition that ecchymosis resulted from poor stunning technique, put forward in some industry manuals (CSIRO, 1995), and that stunner operators could produce ecchymosis at will (Anthony, 1951). Kirton & Frazerhurst (1983) compared the incidence of ecchymosis in lambs subjected to three stunning treatments including:

- Double stunning, in which the lambs were stunned, allowed to recover for 10 to 20 minutes, then stunned again and exsanguinated;
- Light then Normal stunning, in which the lambs were first stunned using 0.5 amps for 0.3 seconds, then stunned again approximately 10 seconds later using 0.75 amps for 1 second, and then exsanguinated; and
- Normal stunning (to simulate correct stunning method) in which the lambs were head only electrically stunned using 0.75 amps for 1 second and exsanguinated using the spear stick method after 5 to 8 seconds.

The double stunned and light then normal stunned treatment groups showed a similar increase in ecchymosis, in comparison with the normal stunned group, with the ecchymosis in the double stunned group being more severe than that in the light then normal stunned group (Kirton & Frazerhurst, 1983). Overall however, the incidence and severity was not as great as that sometimes seen in seemingly normal slaughter lines (Kirton & Frazerhurst, 1983). Importantly, the same authors also mentioned other research conducted by their group which was not published, which found that neither; lamb breed, age, weaning, pre-slaughter handling, including violent exercise, nor electrical stunning parameters had any measurable effect on the incidence or severity of ecchymosis in lambs.

Kirton *et. al.* (1978) investigated the relationship between the interval between stunning and exsanguination and ecchymosis in lambs by comparing carcasses from lambs exsanguinated before electrical stunning, immediately after stunning and, 5 to 8 seconds after stunning and found that that the incidence of ecchymosis went from least to most respectively. This result was consistent with the work on the effect of the interval between stunning and exsanguination on pigs and coupled with earlier work in sheep showing stunning to cause blood pressure elevation, led Kirton *et. al.* (1978) to posit that delays in exsanguination exacerbated the extent to which ecchymosis occurred due to the prolonged elevation of blood pressure.

The effect of stress prior to stunning was investigated in an attempt to explain the different incidences of ecchymosis often seen between seemingly similar mobs of lambs stunned and exsanguinated in exactly the same way, but on different days or at different abattoirs. Pearson *et. al.* (1977) measured circulating cortisol, adrenaline and noradrenaline levels in stunned and non-stunned lambs at different slaughterhouses. Cortisol levels, which are known not to be affected by the stunning procedure itself, and are therefore considered by some to be a reliable indicator of pre-stun stress levels when samples are collected at exsanguination (Shaw & Tume, 1992), differed significantly between slaughterhouses, but there was no association between the levels of this hormone and the incidence of ecchymosis (Pearson *et. al.,* 1977). Adrenaline and noradrenaline levels also differed between slaughterhouses but again there was no association between the levels of these hormones and ecchymosis (Pearson *et. al.,* 1977).

Following commercial reports of high incidences of ecchymosis in lambs sourced from one particular farm, Restall (1980-81) established an association between extended prothrombin times and ecchymosis in mobs grazed on feeds containing high levels of coumarins. As well as affecting prothrombin times coumarins are known to induce blood vessel fragility and either of these factors could be expected to affect ecchymosis.

1.6 Ecchymosis in deer

Incidences of ecchymosis in deer first became a problem upon the commercialisation of deer farming and the subsequent slaughter of deer through commercial abattoirs. Incidences of ecchymosis, in fallow deer in particular, have been reported by people in a number of countries including Australia, The United States, and Canada (Mulley, 1994) and observed in the carcasses of fallow deer slaughtered in New Zealand (Falepau, unpublished). While it is certain that ecchymosis occurs in deer, the extent of the problem has not yet been quantified.

Ecchymosis in deer, as with other species, appears to be associated predominantly with pre-slaughter stunning, although ecchymosis has been observed to occur in deer slaughtered without prior stunning (Falepau, unpublished). However, slaughter of deer without prior stunning was only associated with exceptional circumstances involving emergency euthanasia, where the animal had suffered extensive injury or stress from misadventure.

No literature exists on the occurrence of ecchymosis in deer except for a number of incomplete or unpublished reports communicated at the time of writing by Grogan (1998) regarding work conducted as part of a study on the physiological response of fallow deer to stress. One of those reports concerned an experiment comparing the incidence of ecchymosis in fallow deer stunned by either the head only electrical method or the captive bolt stunning method. The animals used in the trial were non-pregnant fallow deer does less than 20 months of age and they were slaughtered on a sheep slaughter chain comprising a v-conveyer restrainer. The stunning current was said to be 70 volts for 1 second, but this was not confirmed by scientific measurement. The deer were exsanguinated using the gash cut method approximately 5 seconds after stunning. Grogan (1998) reported a significantly higher incidence of ecchymosis in the loins of the electrically stunned fallow deer in comparison with the captive bolt stunned deer. This result was consistent with results in other species reported earlier (Clark & Tweed, 1932; Spencer, 1979; Kirton *et. al.,* 1980-81b).

From the review of the literature, which shows a clear association between the occurrence of ecchymosis and the slaughter of animals through intensive processing systems, particularly with the introduction of pre-slaughter stunning, the lack of previous research into ecchymosis in deer is perhaps reflective of its limited significance worldwide at this point in the development of the industry. It is quite possible that ecchymosis in deer occurs only in those countries from which the reports previously cited were received and where deer were slaughtered through commercial slaughter plants. Putting this into perspective, approximately 400,000 deer are slaughtered through commercial abattoirs in New Zealand each year, and up to 34,000 in Australia in some years, in comparison with far more than this harvested each year in Germany alone, usually by shooting in a paddock. Large numbers of fallow deer are slaughtered in New Zealand and Australia each year and this species, when compared with red deer, appears to be particularly susceptible to ecchymosis.

At the time this study commenced (1996), the only guidelines available to venison processors regarding the minimisation of ecchymosis were those reported in technical publications, which were generally related only to a particular species or slaughter system. Most publications of this nature listed the following means of reducing the incidence of ecchymosis (MIRINZ, 1974; CSIRO, 1984; CSIRO, 1995):

- reduce pre-slaughter excitement and stress;
- rest animals prior to slaughter;
- avoid double stunning;
- reduce time between stunning and sticking;
- ‘pith’ (severance of the spinal cord).

The current study investigated a number of these factors as they applied to the venison processing sector of the Australia deer industry in order to clarify options available to reduce the prevalence of ecchymosis in deer, with particular reference to fallow deer because this condition is most commonly seen in this species.

2. Participatory research in the Australian deer industry

2.1 The adoption of technology - reducing ecchymosis

This project was commissioned by the Rural Industries Research and Development Corporation (RIRDC) on behalf of the elected representatives of the deer industry of Australia (DIAA). The funding for the project was derived from compulsory levies paid by processors and farmers, contributions from the research organisation involved, and the government (RIRDC). A return on the investment of those funds was contingent on the project leading to a reduction in the prevalence of ecchymosis in deer.

From a review of the literature it was apparent that the incidence of ecchymosis could possibly be reduced by the adoption of particular slaughter methods. Much of the experimental work conducted in this project reports the investigation of alternative slaughter methods to determine their appropriateness for the slaughter of deer. What the reduction of ecchymosis in deer in Australia was also contingent on however, was not just the identification and confirmation of appropriate slaughter methods, but also the adoption of those methods by the venison processing sector.

Methodological approaches to research and the development and adoption of technology have been studied in length elsewhere (Chambers, 1983; Bawden *et. al.*, 1985; Roling, 1988; Scoones and Thompson, 1993) and a number of conceptual models have been put forward to depict the various approaches used by those involved in the development process. Roling (1988) put forward that the Transfer of Technology model (TOT) (Figure 2.1) depicted the way in which most scientists perceived the development process, with Chambers (1983) describing TOT as referring to the normal basic paradigm of agricultural research and extension in which priorities for research were decided by scientists and funding bodies, and new technology was developed and then passed on to extension officers for dissemination to farmers.

Using the TOT model the adoption of technology was clearly reliant on two factors; 1) the knowledge of the bureaucrats and/or scientists with respect to identifying research needs and choosing or developing technologies which would be economically and culturally feasible in the commercial environment, and/or 2) the resources and 'salesmanship' of public and private sector extension officers for disseminating information or convincing farmers to adopt new technologies. With respect to the first of these two factors, the level of knowledge of the scientists and bureaucrats regarding the commercial environment could in turn be affected by a number of other factors including the organisational structure of the Research and Development (R&D) sector, the facilitation of communication between scientists, bureaucrats and farmers, and the willingness of farmers to divulge their situation. The factors affecting the extension effort included the industry economies of scale and its effect on the availability of resources for extension activities, and the facilitation of communication between scientists and extension officers.

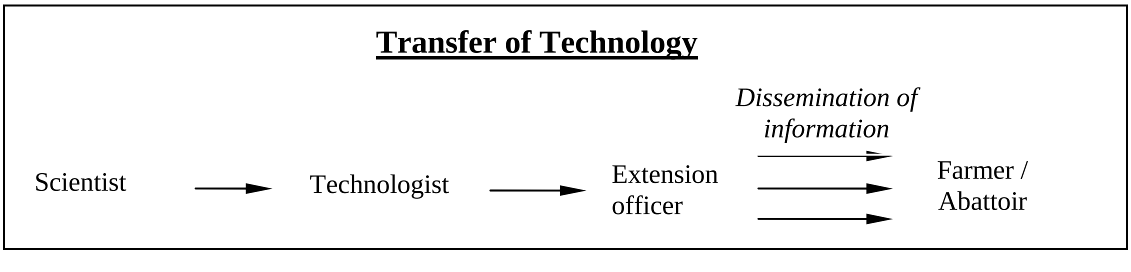


Figure 2.1: Transfer of Technology (After Roling, 1988)

The organisational structure of the Australian deer industry Research and Development (R&D) sector would appear to facilitate the approach depicted by the TOT model in a number of ways. Research priorities were determined by a committee comprising scientists and government bureaucrats and the appropriate allocation of research funds relied on their knowledge of the commercial sector and the importance of various research endeavors to the livelihood of the intended beneficiaries. It was also apparent that the only communication facilitated between farmers and researchers was either from the farmer to the researcher via the bureaucracy or from the researcher to the farmer or extension officer at the conclusion of the research process.

Historically the TOT model could arguably be said to have worked for some time and to some extent in improving agricultural productivity in Western developed nations but has been of limited value in the third world context.

This led to a new philosophical approach to R&D, known as the "Farmer first - farmer last" model (Figure) in which the research and development process began and ended with the farmer in order to better integrate into the design of technologies factors peculiar to the farmers situation, which in turn increased the rate of adoption.

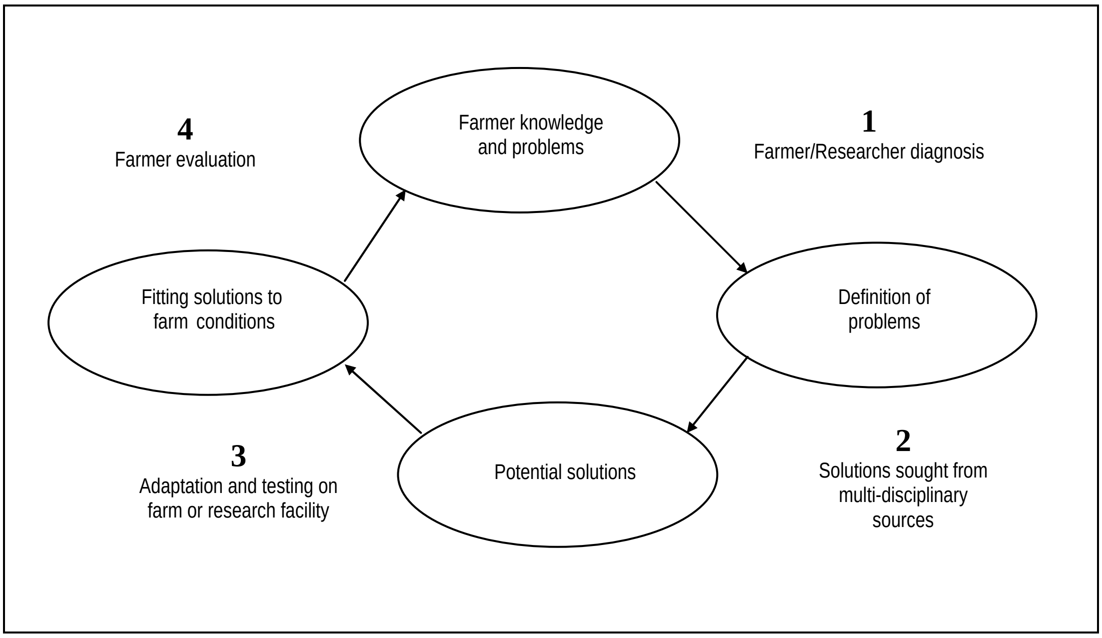


Figure 2.2: Farmer first - Farmer last, a new paradigm for agricultural research

Chambers (1983) described the "Farmer first" paradigm as one in which the learning and locations of TOT were reversed, with farmers playing the major role in technology development and choice. In general the "Farmer first" approach advocated that the 'top down' (Figure 2.3) bureaucratic structure which placed the scientist at the top of the pyramid and the farmers at the bottom as passive recipients of technology, should be changed so that farmers were at least equal participants in the research process.

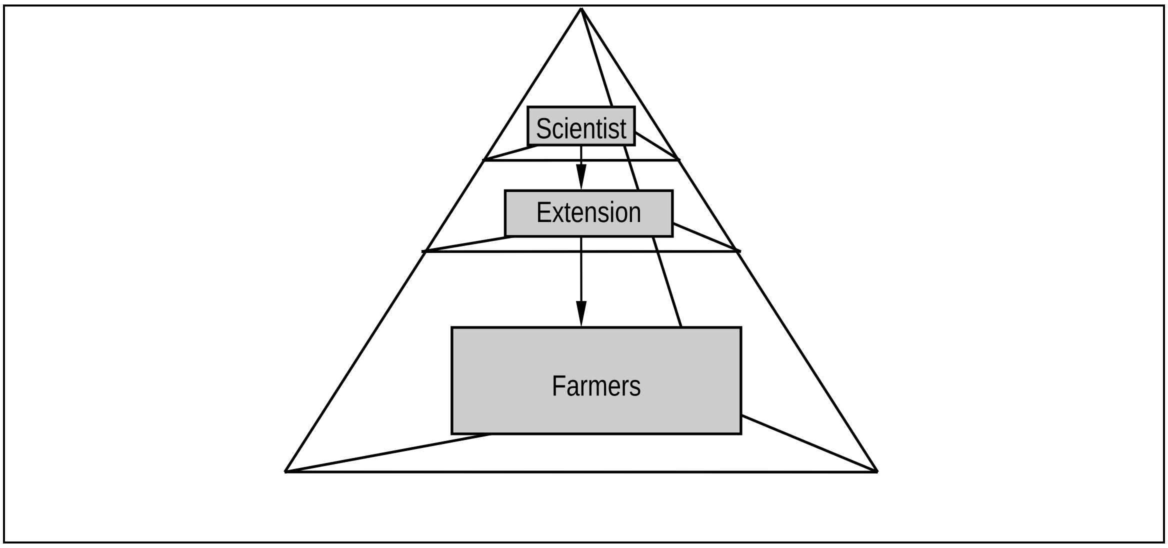


Figure 2.3: The "top down" research and development structure.

While some distinct similarities appear to exist between the organisational structure of the Australian deer industry R&D sector and the TOT paradigm described above, it must be remembered that models are only intended as conceptual representations of real situations. Thus it is possible that none of the conceptual representations presented, accurately depict the R&D process typical of the Australian deer industry. In the current study a number of activities which were inclusive of members of other industry sectors were incorporated into the research process to enable a more accurate depiction of the real situation to be compiled. Inherent in the participatory nature of these activities the notion of farmer participation in the research process as advocated by the "Farmer first" approach was also able to be tested, and factors associated with its potential for implementation in the Australian deer industry assessed.

2.2 Quality control, quality assurance, quality improvement

While the occurrence of ecchymosis in deer was nominated by some as a problem regarding venison quality, by no means could it be suggested to be the only meat quality problem affecting, or likely to affect the profitability of deer farming in Australia. In fact, at the time that the current project was being conducted, the implementation of a Quality Assurance (QA) program encompassing the farming, transport and processing sectors, was also being funded through the DIAA and RIRDC.

Falepau and Mulley (1996) put forward three types of systems (Figure 2.4) aimed at ensuring the quality of a product. The Quality Control (QC) systems were those in which the inspection of the finished product determined its quality, and it was on that inspection alone that the end product was subsequently accepted or rejected for sale. The Quality Assurance (QA) systems synonymous with the deer industry QA program, were those based on a set of documented production and processing practices, expected to be used by those subscribing to the program, which it was suggested would inherently ensure that the product would be one of quality. The final system put forward, Quality Improvement (QI) systems, involved the extension of the QA system by individual producers and processors, to incorporate experimentation regarding alternative methods of production and processing, in order to improve the product beyond the current expectations of consumers, or standards set by others.

Types of Management Systems	Relationship to Consumers and/or Competitors	Impact on Operation	Focus	Attitude Change Required
Quality Improvement	Standard Setter	Ahead of Crisis	Process required for Constant Improvement	'I must always strive to Improve'
	↑	↑	↑	↑
Quality Assurance	↑	↑	↑	↑
Quality Control	Standard Taker	Constantly reacting to Crises	Technology required for Production	'I just need to meet Specifications'

(from Falepau and Mulley, 1996)

Figure 2.4: Beyond Quality Assurance

In relation to Figure 2.4, Falepau and Mulley (1996) suggested that a crisis occurred in most production systems whenever the consumer demanded a change in standards. It was argued that the implementation of a QI system would avoid such crises occurring, and further to this, it could give a company a competitive edge by transforming them into the standard setter, rather than one which had to constantly attempt to comply with standards set by others.

The fundamental changes required to move from QA to QI systems, were put forward to be essentially:

- *operational*, which involved establishing and maintaining a process of inquiry, analysis and innovation, rather than just compliance to set practices; and
- *attitudinal*, which involved developing a desire to improve on, rather than comply with, standards set by others (Falepau and Mulley 1996).

In order to determine the potential for Australian venison processors to move from QC to QI systems, as part of the current project, the mechanisms in place in the processing sector to measure and quantify meat quality were documented.

2.3 The participative approach

The proposal for the need for an investigation into ecchymosis was a reaction to a number of anecdotal reports from farmers and processors that ecchymosis was occurring in deer slaughtered at some abattoirs. However, no data had been recorded to indicate the extent of the problem, and so it was of interest to quantify the prevalence of ecchymosis at a number of different abattoirs. Given that at the time the study commenced, there were a number of different slaughter systems used for the slaughter of deer in Australia, and these comprised many of the methods previously researched in other species, it was also thought that determining the extent to which ecchymosis occurred at each abattoir, would be an efficient way of considering those methods rather than attempting to recreate each slaughter system in a research institute.

Hence, the primary activity of a participatory nature included in the current study involved an attempt to implement recording systems for ecchymosis in abattoirs and boning rooms servicing the venison processing sector in order to quantify the prevalence of ecchymosis detected therein. In addition to this a number of experiments were conducted at commercial abattoirs and the outcomes of these regarding collaboration with the commercial sector is discussed.

In attempting to install ecchymosis recording systems it was also possible to describe in detail the numerous slaughter systems available for the slaughter of deer as a reference for further work related to the venison processing sector including concurrent initiatives toward the implementation of and industry wide Quality Assurance scheme. The descriptions of each slaughter system include both the infrastructural characteristics of the various slaughter premises as well as the organisational structure with regards to management and existing improvement processes. It was also possible while attempting to install the recording systems to inspect and record the prevalence of ecchymosis in deer slaughtered commercially and these are documented with the relevant slaughter systems.

2.4 Attempts at industry collaboration

Attempts were made to implement ecchymosis recording systems in a number of domestic and export abattoirs and boning rooms to determine the prevalence of ecchymosis that occurred in deer slaughtered in Australia. These attempts were documented as case studies indicative of deer industry collaboration with research organisations in order to assess the potential for the development of participatory approaches to R&D which have been observed to improve the development and adoption of technologies elsewhere, particularly in third world agriculture.

Throughout the project a number of experiments were conducted at commercial abattoirs or boning rooms and these are also discussed as case studies of attempts to conduct research collaboratively with the commercial venison processing sector.

Materials and Methods

Ecchymosis Recording Systems

Methods of Contact

The first contact made with processors and farmers was via an article published in the Australian Deer Farmer (ADF) magazine during the first year of the project, which introduced the nature of the project and the people involved in the research team, including collaborators from CSIRO. It also put forward a number of ideas regarding potential factors associated with ecchymosis and invited anyone to become involved by either forwarding ideas on ecchymosis or establishing recording systems. Contact was invited by conventional phone, facsimile, mail or mobile phone with twenty four hour message service. A second article, similar to the first, was also published in the deer industry R&D newsletter at the beginning of the second year of the project.

The second contact made with processors was by phone, with 6 export and 5 domestic venison processors contacted, following which letters were sent to each reiterating the aims of the project and potential methods of recording information on ecchymosis. Of the export processors contacted, one operated in Queensland, two in New South Wales, and three in Victoria. The processors in Queensland and New South Wales each slaughtered and boned at the same location in each of the respective states, and the three in Victoria slaughtered at the same abattoir, with one slaughtering at the NSW export abattoir occasionally. The Victorian processors boned at different locations. The five domestic processors contacted were located in Queensland (1), NSW (1), Tasmania (1), and Victoria (2), with the two in Victoria being exporters also.

The third contact was visiting in person 3 export and 3 domestic boning rooms, which catered for 5 export and 3 domestic processors. One of the export boning rooms was located in Queensland, one in New South Wales, and the other in Victoria. The domestic boning rooms were in Queensland, New South Wales and Tasmania. Two of the export boning rooms and all of the domestic ones had been contacted by the second method. During each visit the aims and time scale of the project were reiterated and systems for monitoring and recording incidences of ecchymosis were established with the people working at the abattoir who were required to be involved. In all cases the manager/s of the enterprise were involved directly in the development of the systems and in every case commitment to the recording of information was pledged. The NSW abattoir and boning room through which three processors operated, was visited three times and at the conclusion of each visit commitment to the recording of information was pledged by management. Arrangements were also made at this establishment for either of two key personnel (secretary and works manager) to notify the author pending forthcoming fallow deer kills.

Collaborative Project

In the second year of the project (1997), a proposal was put forward to the RIRDC and DIAA by two processors slaughtering fallow deer at a domestic abattoir in South Australia to investigate factors associated with ecchymosis project **(BRN-1A)**. The proposal was to investigate a number of pre-slaughter factors that were said by the processors not to have been included in the current study, although it was apparent that this was based entirely on conjecture as despite the proposal acknowledging the existence of the current study, none of the UWSH research team had been contacted by the processors during the 18 months the current project had been operating. The UWSH team were not made aware of the proposal until notified by the RIRDC. In a subsequent meeting convened by the UWSH research team involving DIAA and RIRDC representatives, the lack of success in recording the commercial prevalence of ecchymosis to that time was considered and the project **(BRN-1A)** was funded under a separate contract with RIRDC on the condition that the project was to be carried out in collaboration with the current UWSH project. In collaboration with the UWSH team it was determined that the South Australian processors would record incidences of ecchymosis in deer carcasses both before and after modifications to their slaughter system had been made. The modifications involved the installation of lairage pens and a race to move deer to a sheep restrainer inside the abattoir for stunning. The system that previously existed involved head shooting and exsanguination of the deer outside the abattoir slaughter floor shortly after arrival at the abattoir. The venison processors were visited and with them ecchymosis recording systems were put in place. Recording of ecchymosis was to take place for three months prior to changes being made to the existing slaughter system as that was the time required to make the infrastructural changes, and three months after. RIRDC project (BRN-1A) funded the modifications to the abattoir infrastructure and the contribution from the researchers was to be the recording and collation of the data on ecchymosis.

Information to be recorded by each of the processors was decided in collaboration with the author and included:

- (processor 1) origin of deer, handling frequency prior to slaughter, behavioral response to handling, sex type, age, carcass fat score, number of knuckles and loins affected by ecchymosis over the total kill and, 24 hour pH (optional but included by processor);
- (processor 2) same as processor 1 excluding carcass fat score and 24 hour pH. Ecchymosis in all commercial cuts was recorded voluntarily and corresponded to each individual carcass.

Experiments Conducted at Commercial Premises

UWSH Trials

In order to best utilise funds made available for experimentation using live deer, the UWSH research abattoir was upgraded at considerable expense to the research organisation and a license to slaughter deer for domestic market consumption was obtained. A contractual agreement for the sale of whole carcasses used in experiments conducted at the UWSH abattoir was established with a venison vendor who operated a boning room in close proximity to the abattoir. Approximately 130 fallow deer carcasses from 5 trials were graded for ecchymosis at the vendors boning room and those carcasses affected by ecchymosis were not charged to the vendors account, although they were known to have been sold at retail if the ecchymosis was minimal (< Grade 3). The agreed price for the carcasses was below that commonly paid at the time of slaughter as a gesture of goodwill on behalf of the research team although there was no cost incurred by the vendor as a result of their collaboration.

Type D2 Abattoir Trial

Subsequent to the UWSH abattoir trials one experiment involving 79 fallow deer was conducted at a type D2 abattoir (see description of type D_2 abattoir on page 4) and affiliated boning room. The carcasses were inspected during boning and any meat exhibiting ecchymosis was condemned and not charged to the venison vendors account. Although no expense was incurred by the vendor as a result of the experiment, to reflect the nature of the collaborative approach it was left to the vendor to determine the price paid for the venison and it was agreed that payment would only be made when the venison had been resold by the vendor.

Results

Ecchymosis Recording Systems

The article published in the ADF (reference) and the deer industry R&D newsletter (reference) to initiate recording of ecchymosis by abattoirs, boning rooms and processors produced no response.

Following the phone and mail contact made with the six export and five domestic venison processors, no data regarding cases of ecchymosis were recorded by any of these processors during the course of the project. Of the export processors, one of the Victorians put forward that they had no problem with ecchymosis citing incidences of 5%, with only 10% of those greater than grade 3 (using ecchymosis grading chart, RIRDC, 1996) and no further communication was received from them. The other Victorian processors both pledged to notify the UWSH research team of impending deer kills at either the Victorian or NSW abattoirs they used, so that a visit might be arranged. However, no further communication was received except in one instance 10 months later, when one of the processors had received correspondence from a European customer regarding their having received ‘spotted venison’ which they had never previously seen. The processor only wished to know whether it was possible that the customer may not have seen ecchymosis before and after that no further communication was received. Despite continued attempts by the research team to find out when deer were being killed, co-operation from industry was negligible.

Over the two years following visits to the three export and three domestic boning rooms no information regarding the incidence of ecchymosis was recorded. The UWSH research team was notified of an impending fallow deer slaughter once over the two years by the works manager of the NSW abattoir that was visited 3 times. However, notification was given the afternoon before slaughter and at such short notice a visit could not be arranged.

Regardless of the contacts made with processors throughout the project, by either methods 1, 2, or 3, no data was recorded regarding the prevalence of ecchymosis in deer by any. This was despite numerous follow up phone calls being made by the UWSH research team particularly after the third form of contact was made. Personal invitations from a number of processors to visit abattoirs and or boning rooms were received particularly in the third year of the project, and these were generally prompted by high incidences of ecchymosis in a recent kill. However, due to the sporadic nature of these reports and the fact that no data was actually recorded, these reports were of limited value.

Collaborative Project

For a number of reasons the timetable for the infrastructural changes to the South Australian abattoir was not adhered to and eighteen months after the project (BRN-1) was to have been completed the second data set was still not available for inclusion in the current study. Regarding the data recorded while the old pre-slaughter facilities were still being used, Processor 1 recorded data only for the period of time required by the original contract despite the infrastructural changes being delayed. Processor 1 also did not record fat score or pH as originally proposed. Processor 2 however, continued to record data outside the period originally prescribed in the contract when the modifications to infrastructure did not proceed as planned. Data received from the project (BRN-1) is presented in the section (headed **Collaborative Project** under 2.4 Attempts at industry collaboration).

Experiments Conducted at Commercial Premises

UWSH trials

14 months after the last carcasses were received by the venison vendor only two thirds of the moneys owed had been paid and at the time of writing the balance was still outstanding.

Type D2 Abattoir Trial

Nine months after the experiment was conducted and 7 months after notification was received from the vendor that the venison had been sold and payment would be forthcoming, no payment had been received by the research organisation. At the time of writing this, money is still owing.

Discussion

It was apparent from the results of attempts to install ecchymosis recording systems that although ecchymosis was considered problematic by those who initiated the project it was clearly not considered by any of the processors involved in the study to be worthy of collaboration in attempting to define the extent to which it occurred. This was evident to the extent that in some cases no cooperation was forthcoming when the research team attempted to record incidences of ecchymosis themselves and at no cost to the processors. While it could be suggested that this was a manifestation of the Transfer of Technology (TOT) extension model whereby the priorities for research were decided by scientists and bureaucrats it must be remembered that the current study was initiated by the R&D advisory committee and the UWSH research team *on the direct advice* from a number of venison processors and deer farmers that ecchymosis was incurring an economic loss. The same processors who advised the R&D committee and researchers involved in the current study of the need for this research were amongst those approached to assist in the recording of information. In other cases where the research team received reports from processors regarding considerable numbers of carcasses being condemned because of ecchymosis, on each occasion an invitation to record ecchymosis incidence was again extended but even in these cases no subsequent recording took place.

With respect to the potential application of the “Farmer first” approach for R&D in the Australian deer industry it was apparent that recognition of the existence of a problem by researchers and processors[1], which was the first stage of the “Farmer first” process, did not necessarily imply a desire by the processors themselves to participate in further investigating the problem. This may have been because the quantification of the prevalence of ecchymosis was not perceived by processors as necessary to determining ways of reducing it, or that while recognition of the prevalence of ecchymosis may have been comfortably discussed in

[1] Described as ‘farmer’ in the model put forward earlier.

confidence, public declaration by direct involvement in the research process may have been seen as undesirable. This later point was confirmed in part when one of the processors who instigated the current study, presented at national deer industry forum[2] declaring that ecchymosis did not occur in deer slaughtered at the abattoir at which the majority of his deer were processed. This was in contrast with case study data collected in the current study from the abattoir concerned. While the "Farmer first" approach to R&D may be applicable perhaps to situation improvement where the current situation is not perceived as problematic to begin with, in studies such as this where a commercially sensitive problem exists attempts to research the problem with commercial operators may be ineffective.

One of the concerns regarding the TOT process was that its success was in part dictated by the ability of the R&D advisory committee to prioritise research that reflected commercial needs. From the results of the current study it was shown clearly that ecchymosis was prevalent in commercially slaughtered fallow deer and economic losses were occurring whether processors wished to divulge this or not. From the current study it would appear that the initiators were well informed of the current situation, and the recording of ecchymosis that eventuated in the current study was sufficient to confirm the extent of the problem. It may have been excessive to attempt to quantify the prevalence of ecchymosis further.

While the unpaid participation of processors in the current study was negligible, the case studies that were conducted as part of the participatory approach and the experiments conducted at commercial abattoirs enabled researchers knowledge of the slaughter systems available to the venison processing sector to remain current. This facilitated the continual review of the controlled experimental approach, which was intended to reflect the commercial situation in which potential technologies for the reduction of ecchymosis were required to be implemented. This was consistent with the general notion of the "Farmer first" approach and constituted perhaps a 'hybridisation' of both the TOT and "Farmer first" models which could be considered further. As a result the methods of slaughter determined by the current study to reduce the prevalence of ecchymosis could be implemented immediately in the Australian venison processing sector at negligible cost.

From the experiments conducted at commercial premises it was apparent that either:

- the processors involved did not consider agreements made with the UWSH research team in the same way as they did with other suppliers of animals for slaughter; or
- the venison processors treated every supplier in the same way, and the viability of venison processing was such that it was uneconomical to pay for animals.

With respect to the collaborative project (BRN 1), the benefit to the current study was negligible due to unforeseen commercial conditions. However, it would be of interest in considering further the "Farmer first" model to monitor the results of the project (BRN 1) with respect to the effect that external funding of experimentation in the commercial sector has on the adoption of the derived technology. The experimental design of the project (BRN 1) was such that should a greater incidence of ecchymosis occur after the infrastructural changes are made, it would be expected that as the intention of the project was to reduce ecchymosis, the slaughter system would revert back to the original methods.

From the outcomes of the current study it was apparent that with respect to the Australian deer industry, research activities based on conventional business principles or funding of farmer experimentation would either be economically unsustainable or of negligible benefit to the wider industry. It is possible however that partnerships of this nature between the research and commercial sector may be of benefit to the development and uptake of technology in other agricultural industries.

[2] Australian National Deer Industry Conference, Adelaide, 1998.

3 General materials and methods

3.1 Ecchymosis grading

The examination of carcasses for ecchymosis in all experiments and case studies reported in this study was carried out by the same person unless otherwise stated, in order to maintain a level of consistency in judging the severity of the ecchymosis exhibited. To aid in quantifying the severity of ecchymosis a grading chart developed in a preliminary project to the current study was used as a guide (Appendix 1). Due to the lack of distinction between grades 2 and 3 in the denvered loin shown on the chart, only the knuckle/round grading chart component was used to allocate ecchymosis grades regardless of whether the muscle graded was denvered or not. The knuckle is hereafter referred to as the round, being the name most commonly used by people in the commercial venison processing sector during the current study. The round component of the grading chart was used to grade all muscles inspected.

Throughout the current study there were three levels of dissection referred to with respect to the grading of ecchymosis:

- whole carcass or chiller grading;
- the commercial breakdown of carcasses in a boning room; and
- complete dissection.

The chiller grading technique was developed to enable the rapid grading of large numbers of carcasses at abattoirs. The technique involved the removal of the lateral apex of the *M. tensor fasciae latae* to expose the distal surface of the round, more specifically the *M. vastus lateralis*. The muscle surface visible was then scored for ecchymosis. While only the left knuckle ecchymosis score was recorded in this way for case study data collection, in more controlled experiments the *M. subcutaneous trunci* was also removed to expose the dorsal surface of the *M. longissimus dorsi* to provide a more accurate chiller assessment in case the boning room grading should fail to take place. This could also be incorporated into a commercial inspection system. Discussion of the relevance of these sites as indicators of ecchymosis in other carcass muscles was included in the current study.

The grading of carcasses for ecchymosis in boning rooms involved the inspection of commercial venison cuts as described by AUSMEAT specifications (Appendix 2), as they were being removed from the whole carcass. Using this method, only ecchymotic lesions visible on the external surfaces of some of the muscles comprising the particular commercial cuts were graded. The muscle surfaces visible and/or inspected in the hind leg and shoulder, include:

- the dorsal surface of the striploin;
- the internal and external surfaces of the rump;
- the round after removal from the hind leg, and complete removal of the *M. tensor fascia lata;*
- the internal and external muscle surfaces of the topside (*M. adductor femoris*, *M. semimembranosus*) and silverside (*M. semitendinosus*, *M. biceps femoris*), after removal from the hindleg;
- the *M. supraspinatus* situated in the shoulder; and

- the muscles visible in the abdominal and thoracic cavity including the tenderloins (*M. psoas major*), internal and external abdominal muscles and the diaphragm.

The complete dissection of carcasses in the current study to determine the distribution of ecchymotic lesions was conducted using the method described by Butterfield & May (1966).

3.2 Bodyweight

During the course of the current study it was observed that weighing of deer prior to slaughter was not a common practice commercially. The suppliers of deer for slaughter were usually paid by the venison processor on a carcass weight basis after slaughter. In order not to subject deer used in the current study to stress uncommon to commercial slaughter systems, in trials where live-weight was not likely to vary considerably between deer based on visual assessment, or where live-weight was not a factor considered crucial to the analysis or interpretation of the data, the deer were not weighed prior to slaughter.

In all studies where live-weight was not recorded or included as a factor in the analysis of the data the mean carcass weight measured just prior to chilling is presented in the materials and methods rather than the results section, as it bears more relevance to the description of the animals.

3.3 Blood sampling

Blood plasma Sample Collection

Blood was collected either by jugular venepuncture, from deer blindfolded and restrained in a v-drop floor crush, or exsanguination at slaughter. In both cases blood was collected into lithium heparanised vacutainers (Bacto Lab Supplies, Sydney, Australia) and centrifuged for 15 minutes at 3500 rpm to separate plasma. Plasma was then frozen and stored at -20°C.

Cortisol method using DPC Iodinated Tracer

Samples were analysed in duplicate using a second antibody assay. The antiserum was raised in a New Zealand white rabbit against 4-pregnen-11β, 17, 21 - triol - 3, 20 - dione 3 - CMO :BSA. Cross reactivities were, 11- deoxycortisol 8.0%, cortisone 40.5%, 6β hydroxycortisone 2.6%, corticosterone 5.2%, 21 - deoxycortisol 2.2% and progesterone <0.1%. The iodinated tracer was supplied by Diagnostic Products Corporation (Los Angeles, CA). Standards were made in charcoal stripped deer plasma.

Duplicate 5μl samples or standards were incubated overnight with 100μl buffer, 200μl tracer and 100μl antiserum used at an initial tube dilution of 1:5000. The tubes were incubated for 24 hours at 4°C. On day two 100μl of pre-precipitated sheep anti-rabbit second antibody was added and the tubes were incubated for 2 hours at 4°C. Before centrifuging at 1800g for 35 minutes, 1ml of buffer containing 8%W/V polyethylene glycol 6000 was added. Dilutions of a high cortisol plasma in charcoal stripped plasma were parallel to the standard curve.

Cervine progesterone method using DPC Iodinated Tracer

Samples were analysed in duplicate using a second antibody assay. The antiserum was raised in a rabbit against progesterone 11-hemisuccinate:BSA. Cross reactivities were <0.1% against the following steroids. Testosterone, androstenedione, oestradiol-17β, cortisol, 20β-hydroxyprogesterone, 20α-hydroxyprogesterone, 17α-hydroxyprogesterone, pregnenolone, epitestosterone, androstenediol, androsterone, androstanedione, 11β-hydroxytestosterone, oestrone, oestriol and oestradiol-17α. The iodinated tracer was supplied by Diagnostic Products Corporation (Los Angeles, CA). Standards were made in charcoal stripped cervine plasma.

Duplicate 10μl samples or standards were incubated overnight with 50μl buffer, 200μl tracer (10 000 counts/minute) and 100μl antiserum used at an initial tube dilution of 1:30 000. The tubes were incubated for 24 hours at 4°C. On day two 100μl of pre-precipitated sheep anti-rabbit second antibody was added and the tubes were incubated for two hours at 4°C. Before centrifuging at 1800g for 35 minutes, 1ml of buffer containing 8%W/V polyethylene glycol 6000 was added. Dilutions of a high progesterone plasma in charcoal stripped plasma were parallel to the standard curve.

Testosterone method using DPC Iodinated Tracer

Samples were analysed in duplicate using a second antibody assay. The antiserum was raised in a sheep against testosterone 3CMO human α globulin conjugate. It had negligible cross reactivity (<0.08%)with progesterone, cholesterol, β-estradiol, estriol, 17α-hydroxyprogesterone, androsterone, epiandrosterone and 0.67%- 4-androsten-3,17-dione, 0.64%- 17α-epitestosterone, 5.04%- 5α-androsten-17β-ol-3one. The iodinated tracer was supplied by Diagnostic Products Corporation (Los Angeles, CA).

Duplicate 20μl samples were incubated overnight with 50μl buffer, 200μl tracer and 100μl antiserum used at an initial dilution of 1:22 000. On day two 100μl of pre-precipitated donkey anti-sheep second antibody was added (Pel Freeze, Rogers Arkansas) and the tubes were incubated for a further 2 hours at 4°C. Before centrifuging at 1800g for 35 minutes, 1ml of buffer containing 8%W/V polyethylene glycol 6000 was added. Dilutions of a high testosterone plasma were parallel to the standard curve.

3.4 Exsanguination methods

The two methods of exsanguination referred to as the thoracic stick and gash cut methods of exsanguination (Figure 3.1) were previously described by Blackmore & Newhook (1976).

The thoracic stick method was described as a "midline cranio-caudal incision between the first two ribs severing the major vessels (bicarotid trunk and cranial vena cava) within the thoracic inlet" (Blackmore & Newhook, 1976). The gash cut method was described as "the traverse incision of the extended neck which almost simultaneously severs the trachea, esophagus, common carotid arteries, jugular veins and the spinal cord at the occipito-atlantal junction" (Blackmore & Newhook, 1976).

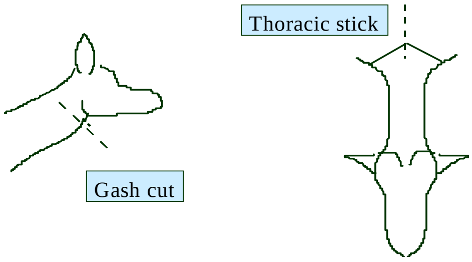


Figure 3.1: Methods of exsanguination (After Blackmore and Newhook, 1976)

3.5 Restraint devices

Four types of deer restraint were used in the current study, referred to as the v-restraining conveyer, the v-drop floor crush, the squeeze crush and the knocking box.

3.6 Stunning

Head-only Electrical Stunning

All of the electrical stunning conducted in the current study only involved the head only method. The current was delivered via conventional hand-held electrodes consisting of two sharply pointed steel probes spaced 5 cm apart (Indel Stunner; Jarvis, Sydney, Australia). The probes were applied transversely across the dorsal surface of the neck approximately 2 cm caudal to the ears with enough downward pressure to pierce the skin. The stunning apparatus allowed voltage selections of between 100 and 400 volts, at 50 volt intervals and, current duration could be set between 1 and 4 seconds. The frequency of the current was 50 Hz. An ammeter was installed in the stunning unit to allow the peak current delivered at each stun to be recorded.

Captive Bolt Stunning

A penetrative captive bolt stunner was used with a No. 13 (yellow) charge normally used for sheep, pigs, horses and light cattle (Schermer & Co., Ettlingen, Germany). The bolt was applied in either the poll or frontal position.

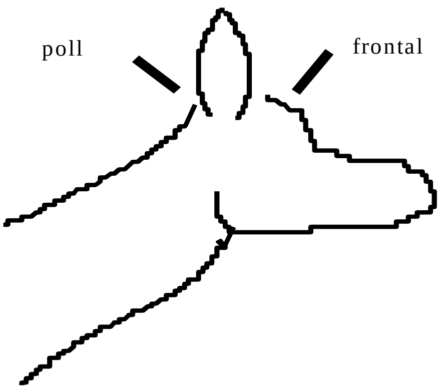


Figure 3.2: Penentrative captive bolt positions

3.7 UWSH abattoir and deer research farm

Due to difficulties in attempting to conduct experiments in commercial abattoirs, the UWSH abattoir was adapted to accommodate deer and was licensed to slaughter for the domestic market. The abattoir comprised a large outside yard with two metres high walls into which the deer were received after being moved from the farm handling shed across the road. At the opposite end of the yard from where the deer entered, a raceway extended into the abattoir building and two fully enclosed dark rooms where the deer were held prior to slaughter. In the corner of one of the dark rooms a ramp led up into a drop floor crush described previously, in which the deer were restrained for stunning . The deer were goaded into the ramp one at a time by closing a large door around behind the group.

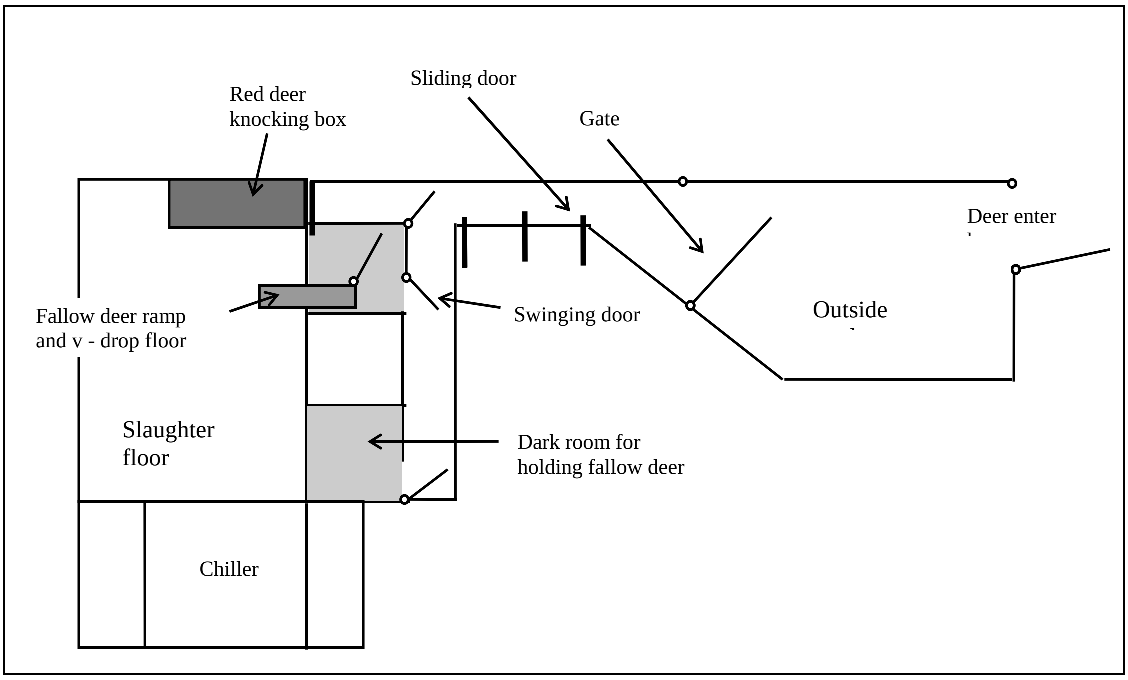


Figure 3.3: UWSH abattoir and holding yards.

The UWSH abattoir was located adjacent to the UWSH deer research farm with the length of the laneway along which the deer were moved between these locations being approximately 180 metres. The deer farm comprised approximately 10 hectares divided by a road over which the deer traveled from the farm handling shed to the abattoir, or adjacent paddocks. The pasture comprised mainly Kikuyu, some couch, and the smaller paddocks on the eastern side of the road dissecting the farm were over sown annually with oats and ryegrass for winter feed. These paddocks were also irrigated. The paddocks on the western side of the road were predominantly Kikuyu and had no recent history of pasture improvement, nor were they able to be irrigated. Buildings comprising the campus of the UWSH bounded the western and southern perimeters of the farm, but the northern and eastern boundaries were adjacent to farm land. No other species of livestock were given access to the farm and only two people were involved in the day to day management of the unit including moving deer from paddock to paddock and occasional supplementary feeding.

The UWSH abattoir was located adjacent to the UWSH deer research farm with the length of the laneway along which the deer were moved between these locations being approximately 180 metres. The deer farm comprised approximately 10 hectares divided by a road over which the deer traveled from the farm handling shed to the abattoir, or adjacent paddocks. The pasture comprised mainly Kikuyu, some couch, and the smaller paddocks on the eastern side of the road dissecting the farm were over sown annually with oats and ryegrass for winter feed. These paddocks were also irrigated.

4 Slaughter systems case studies

4.1 Introduction

Attempts to implement recording systems in boning rooms and abattoirs enabled the description of five types of slaughter systems operational in Australia over the course of the current study to be compiled. Carcasses were inspected and graded for ecchymosis at commercial abattoirs and boning rooms, using the ‘chiller’ method developed during this study (see general methods.

The five slaughter systems encountered during this study are referred to as type A, B, C, D or E abattoirs.

The descriptions of each slaughter system include:
1. the general history of the abattoirs and who they service;
2. typical throughput (Cattle and sheep based on maximum potential throughput, and deer based on typical number per consignment);
3. lairage conditions, restraint method, stunning method, and interval between stunning and exsanguination;
4. any information recording system already in place; and
5. the prevalence of ecchymosis where it was possible to grade carcasses.

4.2 Case study 1 - local domestic abattoirs

History

These abattoirs were licensed to slaughter for domestic markets only and were located in rural towns on the fringes of major cities, to cater for the local meat trade. These abattoirs were some of the first in Australia to slaughter deer as deer farmers began supplying small numbers of carcasses to butcher shops and restaurants in their home towns towards the end of the investment phase. While type A abattoirs were amongst the first to slaughter deer, few invested in permanent holding facilities for deer. This was probably due to the size of the local markets for which only a small number of carcasses were required each week. Type A abattoirs would probably only cater for about 10% of the deer slaughtered in Australia each year, based on the fact that 85% of Australian venison is exported (RIRDC, 1995) and some of the deer slaughtered for export may eventually be traded on the domestic market.

Daily Throughput

Type A abattoirs were generally capable of slaughtering approximately 50 cattle or 200 sheep in a day. While they could potentially slaughter 60 red deer or 80 fallow deer per day (based on the similar type D2 abattoir), as mentioned earlier the size of the local domestic markets meant that generally only between 10 and 30 deer were slaughtered each week.

Pre-stun Treatment

Deer slaughtered at type A abattoirs were generally mustered the day prior to slaughter and held over night in the yards on the farm. The following morning they were transported to the abattoir using a trailer or small truck especially designed for carrying deer. In most cases transport times were under an hour. The deer were the first animals slaughtered on the day, with sheep or cattle slaughtered for the remainder. A number of variations existed between the type A abattoirs with regard to the restraint and stunning methods employed for deer. The deer were either:

- unloaded from the transporter, down a short race into a conventional cattle knocking box where they were stunned using a penetrative captive bolt (type A1);
- goaded into a smaller knocking box built especially for fallow deer, installed in the transporter or attached to it (A2); or
- head shot using a .22 calibre firearm while free standing in the transporter (A3).

The interval between stunning and exsanguination was observed to vary between type A abattoirs with the interval being generally greater than 75 seconds with the type A1 system, about 10 seconds with the type A2 system, and often more than 5 minutes with the type A3 system.

In all type A abattoirs the method of exsanguination employed was the thoracic stick method. Except for type A2 abattoirs at which the deer were exsanguinated while laterally recumbent, all deer were exsanguinated after shackling and hoisting by a hind leg.

Carcass Processing

Some of the processors that used type A abattoirs also used boning facilities located at the abattoir while others used their own boning rooms located elsewhere. What was common to all processors was that they were directly involved in some part of the boning or packaging process.

Information Recording Systems

Individual carcass weights were recorded at the abattoir on a daily kill sheet prior to chilling and in most cases a tag was attached to the carcass which also had the weight recorded on it. This enabled the venison vendor for whom the deer were slaughtered to trace the carcasses back to the live animal supplier (for payment purposes). Carcasses could not be traced back to individual deer unless live deer identification such as an ear tag, corresponded with carcass identification.

Recorded Incidences of Ecchymosis

As a condition of the collaborative project (BRN-1A) (Barnes *et. al.* (1997), South Aust.), which was expected to be conducted concurrently with the current study data recorded on the prevalence of ecchymosis in carcasses of fallow deer slaughtered using the type A2 and type A3 slaughter systems described previously were obtained for inclusion in this case study. 334 fallow deer slaughtered in 12 separate kills of approximately 25 deer each using the A2 slaughter system were examined over a 3 month period for ecchymosis in the left round. 17 % exhibited ecchymosis in the left round. 134 deer slaughtered in 14 separate kills of approximately 10 deer each were slaughtered using the A3 slaughter system over a three month period. 17 % exhibited ecchymosis in the left round although none of the scores were greater than grade one.

4.3 Case study 2 - large multi-species export abattoirs

History

Type B abattoirs were established to slaughter all species of livestock including sheep, goats, cattle and pigs, for export markets. Most held accreditation for export to a number of countries including Europe, USA and Asia. A number of type B abattoirs, generally one in each state, began slaughtering deer during the 1990's when consignments of over 100 deer became common as the export venison trade grew. Lairage pens were built at these abattoirs to accommodate deer usually by interested venison vendors and the abattoir combined. Around 1996, a number of facets of the Australian meat industry changed, including (i) the privatisation of many of these abattoirs which had initially been owned by local county councils, and (ii) an increase in meat inspection costs. As a result of these and other changes two type B abattoirs in NSW and Victoria that had previously slaughtered deer either closed completely or ceased slaughtering deer in order to downsize for restructuring. This left only one type B abattoir in NSW, which was not accredited to slaughter for European or USA markets, to cater for all the eastern states. By the end of the current study (1998) the type B abattoir in NSW was applying for European and USA accreditation and one of the other type B abattoirs which had previously slaughtered deer recommenced.

Daily Throughput

Type B abattoirs were generally capable of slaughtering approximately 500 cattle and 3000 to 5000 sheep in a day. While they could potentially slaughter the same number of red and fallow deer per day as cattle or sheep respectively, consignments of less than 300 fallow or 200 red deer were more common as lairage space for deer was limited.

Pre-stun Treatment

When there was at least one type B abattoir in each state (1995) slaughtering deer, transport of deer from the farm to the abattoir generally took less than 4 hours. As type B abattoirs closed (1996) and deer had to be carted interstate, journeys of over 10 hours became common. Then, by the time some of the type B abattoirs resumed slaughtering deer (1998), most of the venison traders had formed alliances with other abattoirs and they continued to transport deer interstate regardless. Deer were usually yarded, loaded and transported to the abattoir the evening prior to slaughter and held in lairage at the abattoir overnight. At type B abattoirs part of the existing sheep, goat and cattle yards were converted into deer holding pens for fallow and red deer respectively, and as such the deer were held in lairage overnight adjacent to sheep, goats and cattle. As a consequence, the deer were subjected to unfamiliar noises such as barking dogs, which accompanied sheep, goat and cattle handling. Electric goads were also observed to be used on deer by some of the stockmen. Fallow deer were slaughtered using the sheep and goat slaughter system, which comprised a v-restraining conveyer in which the deer were stunned and then ejected onto a table for subsequent exsanguination. On the exsanguination table the deer were hung by the hind legs from the dressing out rail just after the slaughterman carried out the exsanguination procedure. Red deer were slaughtered using the cattle slaughter system, which was similar to that used in type A1 abattoirs where they were stunned in a conventional cattle knocking box, fell out of the box onto the slaughter floor and were subsequently exsanguinated.

At the type B abattoir which remained in operation throughout the current study all fallow deer were head only electrically stunned using a voltage-controlled stunner. The voltages observed being used for fallow deer were either 110 or 150 volts. Red deer were stunned using a percussion stunner. All deer were slaughtered in accordance with ritual slaughter requirements and hence the gash cut method of exsanguination was the only method employed.

The interval between stunning and exsanguination for the fallow deer was observed to be less than 5 seconds and for red deer approximately 10 to 15 seconds.

From discussions with processors who had previously used other type B abattoirs, some had used the thoracic stick method of exsanguination or permutations of it, rather than the gash cut method.

Carcass Processing

In general the venison vendors using type B abattoirs had little or no involvement with the slaughtering or processing of the deer. The deer were often transported to the abattoir by contract livestock carriers and may have come from any number of sources. The carcasses were boned out by contract boners at any number of locations, often interstate. Following the closure of a type B abattoir used by Victorian processors, live deer were being transported for slaughter from Victoria to NSW, a journey of over eight hours. The carcasses were then returned to Victoria for processing. The vendors often saw nothing of an entire consignment except for the relevant paper work. Seldom did one company control both the slaughter and boning out procedures, even when the carcasses were processed in boning rooms adjacent to the slaughter floor. At the type B abattoir which remained in operation throughout the current study the boning rooms adjacent to the abattoir were leased to a separate company which only sporadically processed deer carcasses.

Information Recording Systems

At the type B abattoir operating during the current study the same information was recorded for both red and fallow deer. Individual HCW's were recorded on a computer prior to chilling and a label which included the date of slaughter, carcass weight, carcass number, owner, and species was attached to the carcass. This enabled the venison vendor, for whom the deer were slaughtered, to trace the carcasses back to the live animal supplier (for payment purposes). Live animal identifications were not recorded. A number of different people were involved in the inspection process including two or three meat inspectors, their supervisor, and a veterinary inspector, and a number of different people were responsible for tagging and weighing the carcasses. One inspector at a time was responsible for inspecting the carcasses just prior to washing, for bruising, broken bones or physical contamination, but they were located away from the tagging area.

Recorded Incidences of Ecchymosis

The left round of 365 fallow deer carcasses were examined for the presence of ecchymosis (Table 4.1) using the 'chiller' grading method previously described. The carcasses originated from 5 separate groups of deer slaughtered using head only electrical stunning and the gash cut method of exsanguination. The source of the deer for each kill was unknown and may have comprised deer from a number of different farms. Each kill occurred on a different day.

Table 4.1: Ecchymosis observed in the carcasses from fallow deer slaughter at a large multi-species abattoir by electrical stunning and the gash cut method of exsanguination.

Month	Ecchymosis grade					Number of animals	Live weight range (kg)	% ≥ Grade 1	% ≥ Grade 2
	0	1	2	3	4				
Feb	32	28	10	6	3	82	27-42	57	23
Feb	85	7	1			93	22-60	9	1
Feb	40	32	11			83	26-52	52	13
Feb	54	3				57	17-27	50	0
Feb	45	5				50	19-56	10	0
Total	259	75	22	6	3	365		29	8

NB: Variation in prevalence of ecchymosis between batches of deer.

Two venison vendors who had fallow deer slaughtered at another type B abattoir that used the thoracic stick method of exsanguination rather than the gash cut method, reported that they had very few incidences of ecchymosis. The abattoir closed just as the project commenced (1996). Another vendor, who also slaughtered fallow deer at another type B abattoir used the thoracic stick method shortly after (10 seconds) the gash cut and this was also claimed to reduce ecchymosis.

4.4 Case study 3 - large vertically integrated enterprises

History

The type C abattoir existed as part of a vertically integrated enterprise comprising; livestock acquisition, slaughter, boning, packaging and marketing. The operation slaughtered and processed a number of species of livestock for export to Europe, including horses and deer, and the same slaughter system was used for all. Generally, only one species was slaughtered on a particular day. Occasionally the type C abattoir slaughtered deer for other venison vendors, but this was not considered a core activity and accordingly slaughter charges were reported by other vendors to be considerably greater than those charged elsewhere. No fallow deer were slaughtered at the type C abattoir, only red or rusa deer.

Daily Throughput

The daily capacity of the abattoir was approximately 200-300 red or rusa deer, which could be held in lairage overnight.

Pre-stun Treatment

The holding facilities for deer comprised shade cloth and steel mesh extensions to horse yards located outside the abattoir, with the race way to the stunning box partly covered by a roof. The floors of the yards and raceway were concrete. The deer were hosed down in the larger holding pens prior to groups of 10 to 15 being drafted off into the first part of the raceway in which they were showered. The showered deer were then drafted consecutively in to smaller groups using a series of sliding doors in the raceway leading from the shower to the stunning box door. Each deer was singled out by the time it reached the last section of the raceway, if not before. The use of an electric goad was observed being used to move deer in the raceway. The deer were stunned in a conventional cattle knocking box with a swinging door installed inside to reduce its internal dimensions. Deer slaughtered at the type C abattoir could come from anywhere between 2 and 12 hours away.

All deer were stunned using a penetrative captive bolt after which they were pulled from the knocking box and pithed. Pithing involved the driving of a pointed knife in a cranial direction into the brain from a point at the back of the head approximately 3 cm caudal to the ears and above the occipital atlantal junction. Pithing occurred approximately 20 seconds after stunning.

The deer were then shackled and hoisted by a hind leg and exsanguinated using the thoracic stick method approximately 2 minutes after pithing.

Carcass Processing

One feature of the type C abattoir was that the entire processing chain from the abattoir to the distribution network was operated by the same company. The boning room was attached to the abattoir and one person oversaw the entire operation.

Information Recording Systems

Generally, only one veterinary and one meat inspector were employed on the slaughter floor and about 15 staff. Tagging of carcasses was the same as at type A abattoirs. Carcasses were weighed and weights were recorded on a sheet in the order of kill. Only the HCW's and order of kill were recorded on the tags attached to the carcass. The tags were then removed prior to entry of the carcasses into the boning room.

Recorded Incidences of Ecchymosis

174 and 83 rusa deer from two different farms were slaughtered in two separate kills at the type C abattoir. The prevalence of ecchymosis for each kill was determined at the boning room as the number of loins (*M. longissimus dorsi*) condemned from export. Only severe cases of ecchymosis, grade 3 or worse were observed to be

condemned. Of the 174 deer slaughtered in the first kill, 16 loins were condemned (5%). Of the 83 deer slaughtered in the second kill, 58 loins were condemned (35%).

Some information regarding the pre-abattoir treatment of the deer slaughtered in each kill was obtained. The deer slaughtered in the first kill had come from a large semi-intensive deer farm three hours away from the abattoir. They were all entire males of a similar age and all had their antler removed. The deer slaughtered in the second kill came from a farm, which did not implement general husbandry practices but simply mustered deer in for slaughter occasionally. The deer from this farm had been loaded at 6.30 p.m. on the day prior to the kill and transported overnight to arrive at the abattoir at 7 am (12.5 hours). Some of the deer were in velvet antler which had been broken during transport and yarding. Some had hard antler and some were female,. and the deer were mixed during transport and lairage. Slaughtered of the deer began an hour after arriving at the abattoir.

From discussions with abattoir staff it was suggested that running two deer at a time into the cattle/horse knocking box for stunning reduced the incidence of ecchymosis. This was practiced until disallowed by a new veterinary inspector.

4.5 Case study 4 – deer and ratite abattoirs

History

Two types of abattoirs came under this category, those built originally for the slaughter of emu’s and ostriches (D1) and one built primarily for deer (D2). A year after most of the type B abattoirs ceased slaughtering deer the Australian emu and ostrich industries found they had too great a slaughter capacity for the number of birds required to be processed. Alliances were formed between existing abattoirs originally established to slaughter ratites and venison vendors who were unable to get deer slaughtered elsewhere. This occurred at the time (1996-97) that there was only one type B abattoir slaughtering deer in the eastern states and that abattoir only slaughtered according to ritual slaughter requirements. The type D abattoirs were all accredited to export to Europe, USA and Asia.

Daily Throughput

The D1 abattoirs could slaughter approximately 200 fallow deer in a day or 150 red deer, and employed approximately 10 staff. The abattoirs had adjoining paddocks fenced for deer so slaughter capacity was not limited by live animal holding capacity. The D2 abattoir, employing only five or six staff could slaughter approximately 70 red deer or 80 fallow deer. Lairage capacity at the D2 abattoir could cater for little more than one days slaughter.

Pre-stun Treatment

As mentioned earlier, strong allegiances were formed between the management of type D1 abattoirs and individual venison vendors when type B abattoirs ceased slaughtering deer (1996). Subsequently, although alternative slaughter facilities became available (1998) vendors slaughtering at type D1 abattoirs generally continued to do so, and deer were frequently transported to these abattoirs from distances of over eight hours away. The D2 abattoir had the same business structure as the type C abattoir described previously and from personal communications with other venison vendors, the D1 operation, as with the type C operation, was seen to be a competitor. This took precedence over location regarding whether or not other venison vendors would use the facility. The lairage pens at both D1 and D2 abattoirs were fully enclosed within the abattoir building and comprised raised steel mesh floors and steel walls of mesh or railing. At D1 abattoirs deer were often held in pens alongside ratites. However, only deer were slaughtered at the D2 abattoir. At the D2 abattoir deer were misted overnight in lairage. Misting involved spraying a fine mist of water over the deer continuously from an over head sprinkler system. No dogs or electric goads were used at either of the type D abattoirs and staff were generally experienced in deer handling, as it was the core activity. Squeeze crushes were used to restrain the deer for stunning prior to slaughter. These comprised two padded walls as high as the neck of a standing deer, which were moved together hydraulically to confine the deer while leaving its head protruding over the top.

At the D1 abattoir, a head only electrical stunner had been installed and used but staff were unfamiliar with its operation and the deer were not successfully stunned. Deer were stunned using either a bolt, or .22 calibre firearm. At the D2 abattoir, deer were stunned using a penetrative captive bolt. A head only electrical stunner was installed and used but again staff were unfamiliar with its operation and the deer were not successfully stunned.

At the D1 abattoir, all deer were exsanguinated by a ritual slaughterman using the gash cut method after the deer were stunned and dragged forward out of the restrainer. The deer were exsanguinated while recumbent, then shackled and hoisted. The interval between stunning and exsanguination at the D1 abattoir was observed to be as long as 2 minutes and no less than 30 seconds. The shortest interval consistently possible would probably have been about 15 to 20 seconds if the deer were always dragged immediately out of the restrainer for exsanguination.

At the D2 abattoir, the deer were shackled and hoisted prior to exsanguination using the thoracic stick method. Often, a number of deer were stunned in close succession and left to lie in the exsanguination area until a hoist became available. This resulted in intervals between stunning and exsanguination of no less than a minute, and often as much as five minutes, occurring. From subsequent communications with the abattoir management however, the system was changed so that the deer were exsanguinated while recumbent, and immediately upon release out of the side of the restrainer. Consequently, the interval between stunning and sticking was reduced to approximately 10 seconds.

Carcass Processing

At either type D abattoir, carcass processing was under the control of the abattoir management with the D1 abattoir having a boning room attached, and the D2 abattoir had a boning room located elsewhere, but still owned by the same company. The main venison vendor operating out of the D1 abattoir often exported carcasses whole, while the D2 abattoir owner processed all.

Information Recording Systems

At the type D1 abattoir, individual animal identifications were recorded on the daily kill sheet which could then be correlated to the HCW's recorded on another sheet, and the carcass tags. At the D2 abattoir, only HCW's were recorded on the daily kill sheet and carcass tags.

Similar to the type C abattoir previously described the owners of the D2 abattoir had complete control of and involvement with, the entire processing chain through to marketing and distribution. In addition to this the D2 enterprise also comprised a large deer farming operation located an hour from the abattoir, from which deer were frequently acquired.

In contrast, the main venison vendor operating out of the type D1 abattoir often saw nothing of a consignment of deer except the relevant documentation, although they did operate a number of share-farming arrangements, and therefore could acquire a reasonable knowledge of the animals they slaughtered and their pre-slaughter history.

Recorded Incidences of Ecchymosis

The left rounds of the carcasses of 134 fallow deer (Table 4.2), and 94 red deer (Table 4.) were examined for the presence of ecchymosis using the 'chiller' grading method previously described. The deer were slaughtered at the type D1 abattoir by shooting with a .22 firearm or percussion stunner, and exsanguinated using the gash cut method. Blood samples were collected at slaughter and circulating cortisol and testosterone levels were measured.

Table 4.2: Ecchymosis scores recorded from fallow deer slaughtered at a deer and ratite abattoir by shooting and gash cut exsanguination.

Kill	Farm	Ecchymosis grade					Total	Live weight range (kg)	% ≥ Grade 1 ecchymosis	% ≥ Grade 2 ecchymosis
		0	1	2	3	4				
1	1	37	14	6	1		58	40-53	36	12
1	2	9					9	-	0	0
1	3	34	3	2			39	-	12	5
1	4	8	6	3			17	46-54	53	18
2	4	10	1				11	45-57	9	0
Total		98	24	11	1		134		27	9

Table 4.3: Ecchymosis scores recorded from red deer slaughtered at a deer and ratite abattoir by shooting and gash cut exsanguination.

Kill	Farm	Ecchymosis grade					Total	Live weight range (kg)	% ≥ Grade 1 ecchymosis	% ≥ Grade 2 ecchymosis
		0	1	2	3	4				
1	1	53					53	-	0	0
1	2	40	1				41	-	2	0
Total		93	1				94		1	0

Reports from a D2 abattoir confirmed the same prevalence of ecchymosis as D1 abattoirs in both species. The D2 abattoir used the thoracic stick method of exsanguination while the D1 used a gash cut.

The mean circulating testosterone concentration for the 37 fallow deer from which blood samples were collected was 0.45 *ng/mL* (SEM $\pm$ 0.02). The mean circulating cortisol concentration was 71.22 *ng/mL* (SEM $\pm$ 3.79). When the individual assay data was plotted according to testosterone levels there was no relationship between testosterone and cortisol levels to be observed.

4.6 Case study 5 – purpose-built fallow deer abattoir

History

The type E abattoir was the only deer slaughter facility operating in Tasmania and as both the feral and farmed populations of deer in that state comprised only fallow deer, the abattoir had been designed specifically for slaughter of this species. Previously the slaughter of deer in Tasmania had been accommodated by small slaughter houses located on a number of deer farms. However, due to changes to meat processing regulations these had all ceased operation by 1995. In 1996 the abattoir expanded its services to slaughter ratites also.

Daily Throughput

Three people were employed on the slaughter floor and they could slaughter approximately 50 deer per day. The abattoir had adjoining holding paddocks so slaughter capacity was not limited by lairage space.

Pre-stun Treatment

The abattoir was situated on a small farm fenced for deer, where deer were generally held for at least a fortnight prior to slaughter. This allowed mobs from numerous sources to be sorted into slaughter lines. The pre-slaughter management of the deer involved:

1. yarding a mob often comprising up to 100 deer the afternoon prior to slaughter, and containing them in an yard outside the abattoir overnight;

2. on the day of slaughter groups of approximately 10 to 15 deer were drafted out of the large mob into the first and largest of two completely enclosed dark rooms built of polystyrene filled panels;
3. from the larger room the deer were coaxed into a smaller room which was illuminated, and then darkened once the deer were enclosed within it;
4. from there the deer proceeded one at a time, generally without goading, through a small door opened from outside the room up a fully enclosed illuminated ramp into the knocking box.

The deer which remained outside the abattoir after the required number of deer were drafted off were released back into the paddock. The knocking box was especially designed to fit a fallow deer, with a hole in the front door through which the head of the deer protruded to enable placement of the stunner. All deer were stunned using a penetrative captive bolt stunner, pulled from the crush immediately onto a platform from which they were hung from a rail, and subsequently exsanguinated using the thoracic stick method. The staff were extremely familiar with the system and the interval between stunning and exsanguination was consistently less than 8 seconds.

Carcass Processing

Two days per week were usually spent slaughtering deer, with the same staff then boning out, packaging and processing small goods during the remainder of the week. The boning room was attached to the abattoir. As with type C and D2 abattoirs the entire production chain including livestock procurement, slaughter, boning and marketing was controlled by two people.

Information Recording Systems

HCW's were recorded on the daily kill sheet but no tags were attached. The abattoir operated under a QA program incorporating a Hazard Analysis Critical Control Program (HACCP) required to be implemented by law and this was managed by the abattoir foreman, who was one of three slaughtermen. The foreman also carried out the ante and post mortem inspections, and supervised the boning room.

Recorded Incidences of Ecchymosis

50 fallow deer carcasses were inspected at the type E abattoir in Tasmania during boning, and rounds, loins, and shoulders were inspected for ecchymosis. No rounds or loins exhibited ecchymosis, but 2 carcasses had grade 1 ecchymosis in the shoulder (*M. supraspinatus*) of the left side only.

4.7 Discussion

In each of the slaughter systems studied the only meat quality parameter measured and recorded was carcass weight prior to chilling and in only one case study (type D1) were carcass weights correlated to individual live animal identification. In type C, type D1, type E, and some of the type A systems the boning room was located adjacent to the abattoir and it would have been relatively easy to maintain a correlation between data pertaining to the processed carcass and information related to individual live animals, or at least groups of animals from different sources. With the type D2 system, where the boning room was not adjacent to the abattoir, both existed as part of a vertically integrated enterprise and because the owners had direct involvement in the processing chain from livestock procurement to distribution, again the potential for tracing data from the processed carcass back to the individual live animal was considerable. With the type A systems generally the only part of the processing chain including the farming of the animals, that did not directly involve the venison vendor was the slaughter of the animals. In all but the type B slaughter systems the potential to trace carcass qualities back to individual live animals was considerable and in many systems information pertaining to the history of the live animals was also obtainable. Considering this, the fact that no quantitative data was recorded with respect to the incidence of ecchymosis despite numerous anecdotal reports being received, would suggest that the attitude of most processors to autonomous improvement of meat quality was poor. Generally the operational capacity for quality improvement was good. However, further studies should investigate factors associated with attitudes toward quality improvement in the venison processing sector as a part of further initiatives toward that goal.

The concurrent deer industry QA program is based largely upon the self regulated implementation of best practices and the accurate recording of information related to the pre-slaughter history of individual animals. The results of the current study with respect to the general attitude of processors, of whom many were also farmers, toward reducing a measurable meat quality defect such as ecchymosis, would suggest that few would be expected to implement the QA program with the integrity that is required to ensure the value of the QA mark. This is particularly so as many of the carcass qualities expected to be associated with the QA mark, such as those related to the general welfare of the farmed animal, would not be apparent in the carcasses and non adherence to best practice in most cases would therefore remain undetected.

The results of the current study revealed a wide range of differences with respect to the slaughter systems available in Australia to slaughter deer. Considerable differences were apparent between slaughter systems with respect to lairage, restraint, stunning, and exsanguination. Lairage conditions varied from those at large multi-species abattoirs where deer were contained in pens adjacent to sheep and goats, to those at deer only abattoirs where the deer were misted overnight. In some cases deer were contained on farms overnight and delivered for slaughter the following morning. Various types of restraint were observed including a conventional cattle knocking box, a knocking box purpose built for fallow deer, v-restraining conveyors, and squeeze crushes. The two most common methods of stunning used were captive bolt and head only electrical stunning, although shooting with a .22 calibre firearm and the use of a mushroom head captive bolt were also observed. As a result of the methods of restraint used and the location of the restraining device to the dressing out rail the interval between stunning and exsanguination between slaughter systems also varied from less than 5 seconds to over a minute. Methods of restraint, stunning, exsanguination, and the interval between stunning and exsanguination, and their effect on the incidence of ecchymosis, were investigated in the current study.

As an indication of the prevalence of ecchymosis associated with the various slaughter systems employed for deer, a number of carcasses were graded at commercial abattoirs and boning rooms. It was apparent from the results of the current study that red deer were less pre-disposed to the condition than fallow deer and this was consistent with anecdotal reports received from numerous processors.

The highest prevalence of ecchymosis was recorded in mobs of rusa deer slaughtered at a type C abattoir where the slaughter system was similar to those at type B (cattle) and A1 abattoirs, except for the interval between stunning and exsanguination, which was up to five minutes long. The rusa deer were also subjected to pre-slaughter treatments visually assessed as more stressful than observed at any other slaughter premise.

With respect to fallow deer the lowest prevalence of ecchymosis was associated with type A2, type A3 and type E abattoirs in which slaughter was by captive bolt stunning, thoracic stick exsanguination, and the interval between stunning and exsanguination was generally less than 5 seconds. By comparison the type B abattoir used head only electrical stunning and gash cut exsanguination, and the type D1 abattoir used gash cut exsanguination up to one minute after shooting with a .22 calibre firearm.

Approaches to R&D

The TOT approach to R&D in the deer industry resulted in research being conducted which was appropriate to improving the quality of venison produced in Australia. From the results of the current study it was shown that ecchymosis was prevalent in deer slaughtered in Australia, particularly fallow and rusa deer.

Attempts to incorporate a “Farmer first’ approach to R&D was conducive to the development of appropriate technologies in so much as it enabled the knowledge of the researchers with respect to the commercial sector to remain current. As a result, the choice of factors investigated were consistent with the slaughter systems available for the deer despite frequent changes in this respect occurring throughout the three years in which the project was conducted. Apart from this benefit, conducting experiments in collaboration with commercial venison processors was largely uneconomic. Furthermore, the funding of commercial processors to conduct research was shown in the current study to be of little benefit to the wider industry.

The venison industry showed considerable potential for quality improvement with respect to the capacity to record and monitor quality characteristics and trace these back to individual animals, due to the dominance of vertically integrated business structures, and the small scale of some of the operations. However, the attitude of venison processors toward quality improvement was demonstrated to be poor. From the current study it was apparent that the autonomous improvement of venison quality by venison processors was unlikely to occur, and given this, the potential for the success of self regulated QA schemes may be limited.

Electrical Stunning

From an overview of the development of the venison processing sector, the slaughter of fallow deer was by 1995 accommodated mainly by a number of large multi-species abattoirs using their existing sheep and goat slaughter systems. Type B abattoirs comprised a v-restraining conveyer, at the end of which the deer were head only electrically stunned before being ejected onto a small platform for exsanguination. Just prior to the commencement of this study (1996), there were a number of Type B abattoirs slaughtering fallow deer and in some the thoracic stick method of exsanguination, or permutations thereof, were used rather than the gash cut method exclusively. Anecdotal reports from processors who had been involved with the use of the thoracic stick method at type B abattoirs indicated it to be associated with low incidence of ecchymosis in fallow deer.

At the commencement of this study, all but one of the type B abattoirs in Australia had ceased slaughtering deer. The remaining type B abattoir slaughtered all livestock for the Muslim market and used only electrical stunning and the gash cut method of exsanguination for the slaughter of sheep, goats and fallow deer. At that particular type B abattoir, the Muslim slaughterman would not modify in any way the method of exsanguination in order to reduce the incidence of ecchymosis.

A number of alternative methods of stunning, some of which had been shown to reduce the incidence of ecchymosis in other species of livestock, have already been discussed. They included; head to body electrical stunning, high frequency electrical stunning, carbon dioxide stunning, percussion stunning, penetrative captive bolt stunning, and shooting with a .22 calibre firearm. Barriers to the implementation in the venison processing sector of any of these alternative methods of stunning, broadly include; non-conformance to Muslim slaughter requirements, establishment cost, operating cost, ability to be integrated into existing slaughter systems, safety, and limited knowledge of their application on deer and/or other species.

Of these, non-conformance to Muslim slaughter requirements was the one factor that limited the potential implementation of any of the alternatives to head only electrical stunning. Due to limited marketing opportunities for the small amounts of Australian venison being produced, at the commencement of this study the Muslim market constituted a significant export market. While not all Australian venison was exported to Muslim markets, the Muslim method of slaughter was still preferred so that this market was maintained as an option.

A number of studies have investigated the incidence of ecchymosis associated with electrical stunning in sheep and pigs. Kirton and Frazerhurst (1983) investigated the proposition that poor stunning method caused ecchymosis to occur in lambs, that was put forward earlier by others and cited in numerous technical publications previously discussed. The treatments compared by Kirton and Frazerhurst (1983) included; ‘normal stunning’, using one application of 0.75 amps for 1 second, and ‘poor stunning’ which included both double stunning, involving two applications of 0.75 amps for 1 second at 10 to 20 minutes apart, and light then normal stunning, involving one stun using 0.5 amps for 0.3 seconds followed by a normal stun 10 seconds later. Kirton and Frazerhurst (1983) found that poor stunning technique increased the incidence of ecchymosis significantly, but the increase was not as severe as that sometimes seen in normal slaughter lines. Lambooy and Sybesma (1988) compared ecchymosis in pigs stunned using either 70 volts for 10 seconds, or 475 volts for 3 seconds, and put forward that the lower voltage caused a greater incidence of ecchymosis in pigs.

Head only electrical stunning has been investigated in fallow deer from a welfare perspective, but not in relation to ecchymosis. Blackmore *et. al.* (1993) and Cook *et. al.* (1994a and 1994b) established minimum currents and duration’s required to render insensible red and fallow deer, using electroencephalogram (EEG) recordings of brain function. A state of insensibility being indicated by an epileptiform seizure shown as an increase of EEG amplitude at least five times that observed prior to stunning (Blackmore *et. al.*, 1993). In red deer it was shown to take up to 9 seconds for the EEG to reach the maximum amplitude (Blackmore *et. al.*, 1993), but in fallow deer it was instantaneous upon the application of the stun current (Cook *et. al.*, 1994a). Perhaps related to the EEG recordings, no tonic spasms were observed to occur in the red deer (Blackmore *et. al.*, 1993), but in the fallow deer they were instantaneous upon the commencement of the stun, which was typical also of cattle and sheep (Cook *et. al.*, 1994a). These results suggested the onset of a tonic spasm in fallow deer to be indicative of a state of insensibility having been induced. Tonic spasms in fallow deer were observed to persist for 18 to 22 seconds and clonic kicking movements commenced after 20 to 30 seconds (Cook *et. al.*, 1994a). In fallow deer stunned using a currents of 1.0 or 1.3 amps for 4 seconds duration (50 Hz, 400 V open circuit) EEGs showed evidence of epileptiform seizures lasting from 58 to 68 seconds (Cook *et. al.*, 1994a). Then in a subsequent study using 1.0 amp, 0.2 seconds was determined as the minimum stun duration required to induce an epileptiform seizure (Cook *et. al.*, 1994b). The duration of the epileptiform seizure at the shorter stun duration was 48-54 seconds.

Two types of electrical stunning apparatus have been used for the stunning of fallow deer. A current-controlled device used by Cook *et. al.* (1994a), and a voltage-controlled device commonly used on fallow deer in Australia (Falepau, unpublished). A voltage-controlled device was used throughout the current study. With the voltage-controlled device, both the voltage, and the duration for which the current was required to flow, were pre-selected. Then, within the potential range of the voltage selected, the peak stun current was determined by the level of impedance, or resistance, of the animal tissue through which the electrical current passed. For example in the current study using fallow deer, when the voltage-controlled device was set at 250 volts for 1 second, the peak stun currents ranged up to approximately 1.3 amps. However when it was set at 400 volts for 1 second peak stun currents of up to 3 amps were recorded. With the current-controlled device used by Cook *et. al.*, (1994a and 1994b) the current rather than the voltage was pre-selected. The current-controlled device was constantly set at 400 volts with the peak stun current limited by a series of internal chokes. Thus, the circuitry was such that if 1.3 amps was selected then 1.3 amps was delivered. No work on the electrical stunning of fallow deer other than that using a current-controlled device (Cook *et. al.*, 1994a) has been reported in the literature.

In the course of investigating the effect of electrical stunning on the incidence of ecchymosis in fallow deer a number of other factors were investigated which had been considered by others to have the potential to effect ecchymosis expression. A number of technical publications regarding ecchymosis considered stress prior to stunning as a predisposing factor (MIRINZ, 1974; CSIRO, 1984; CSIRO, 1995) and in pigs, a higher incidence of ecchymosis was observed to be associated with a number of pre-slaughter treatments said to be stressful including:

- the use of an electrical prod, rather than a leather strap (Calkins *et. al.*, 1981);
- transport compared with no transport; and
- restraint versus no restraint prior to stunning (Lambooy and Sybesma, 1988).

Each of these treatments were thought to have stimulated different levels of pre-slaughter stress, although no blood plasma constituents were measured.

Furthermore, Cook and Jacobson (1996) showed that heart rate in domestic livestock was affected by stress, with tachycardia being the most common response although in some circumstances bradycardia has been observed to occur. More specifically, Stephens and Toner (1975), cited by Cook and Jacobson (1996), showed tachycardia to occur in response to restraint. In the current study heart rate was measured during restraint prior to stunning to determine if there was any variation between animals, and whether hear rate during restraint had any effect on ecchymosis. The resident Muslim slaughterman at one of the major export abattoirs, when questioned regarding his criteria for choosing the stunning voltage to be used on fallow deer, revealed a strong opposition to the use of voltages greater than 150 volts, on the basis that they would cause the heart to cease beating earlier than would occur using 150 volts or less. Experiments reported in this section sought to clarify this proposition.

5. Commercial electrical stunning of fallow deer

5.1 Introduction and general methods

At the commencement of this study there was only one type B abattoir available to slaughter fallow deer from Queensland, NSW, Victoria and South Australia for export. One of the main markets at that time for Australian venison was the Muslim market and the type B abattoir concerned slaughtered all fallow deer using head only electrical stunning and the gash cut method of exsanguination. The voltages used to stun deer varied from 70 volts for 1 second reported by Grogan (1998), to 150 volts for 1 second (Chapter 5). It was confirmed by the resident Muslim slaughterman who determined the voltage to be used, that voltages of over 150 volts were never used.

The only work previously reported in the literature on the electrical stunning of fallow deer was by Cook *et. al.* (1994a and 1994b) using a current-controlled device rather than a voltage-controlled device commonly use in Australia. Cook *et. al.* (1994b) used currents of 1.0 and 1.3 amps only and determined the minimum duration required to induce an epileptiform seizure. There are no reports in the literature regarding the use of voltage-controlled stunners for the slaughter of fallow deer. The following trial aimed to determine the peak stun currents achieved using a voltage-controlled stunner on fallow deer, set at 150 volts for 1 second duration, as this was the voltage and duration suggested by the resident Muslim slaughterman to be most commonly used.

5.2 The effect of duration of current on ecchymosis

Materials and Methods

Animals and Slaughter Treatment

A commercial line of fallow deer (n=156) were slaughtered at a type B abattoir. The deer were stunned using 150 volts for a duration of 1 second. The stunner was of the voltage-controlled type previously described, with the exclusion of a permanent ammeter.

Measurement

Peak current for each stun was measured by the resident electrician at the abattoir using a hand held ammeter wired temporarily into the stunning unit. The stunning and exsanguination process was monitored to determine that the stun induced a typical tonic phase reaction.

Analysis

Mean, minimum, maximum and frequency of peak stun currents were determined.

Result

The peak stun currents recorded from 156 deer stunned using 150 volts for 1 second showed a normal pattern of distribution Table 5.1). The mean peak current was 0.79 amps (SEM ± 0.02). The minimum current was 0.4 and the maximum was 1.8 amps.

All of the deer were observed to lapse into a tonic phase reaction typical of an epileptiform seizure and a state of insensibility.

Table 5.1: Distribution of peak currents recorded from head only electrical stunned fallow deer at a type B abattoir using 150 volts for 1 second.

Peak stun current (amps.)	Number of animals
0.4	2 **
0.5	5 *****
0.6	25 *************************
0.7	33 *********************************
0.8	43
0.9	***
1.0	22 **********************
1.1	15 ***************
1.2	5 *****
1.3	1 *
1.4	3 ***
1.5	0
1.6	1 *
1.7	0
1.8	0
	1 *

Discussion

Cook *et. al.* (1994b) determined the minimum stun current duration required to render insensible fallow deer, to be 0.2 seconds when using 1.0 or 1.3 amps. Associated with a state of insensibility deer were also observed to lapse immediately into tonic phase muscular contractions upon the stunning current being applied. All the deer from the current trial were observed to lapse immediately into a tonic phase reaction immediately upon stunning. It was therefore apparent that stun currents as low as 0.4 amps may be sufficient to render fallow deer insensible when the stun current duration is at least 1 second.

5.3 *The effect of electrical stunning voltage and duration on ecchymosis*

The stun current duration commonly used for the stunning of fallow deer in Australia was 1 second, although generally stunning devices could be set to deliver a current for up to 4 seconds if desired. Lambooy and Sybesma (1988) reported a lower incidence of ecchymosis occurring in pigs stunned using 475 volts for 3 seconds, as opposed to those stunned using 70 volts for 10 seconds. In that particular experiment two electrical stunning parameters were involved, both voltage and duration. In the experiment reported in this section, it was initially intended to determine only the effect of current duration on ecchymosis expression, using both one and three second duration's at 100 volts. 100 volts was the minimum voltage possible with the stunning device used and was closest to the 70 volts used by Lambooy and Sybesma (1988) and reported by others (Grogan, 1998) to be used on fallow deer. However, in commencing the experiment the first deer to be slaughtered was not successfully stunned using 100 volts for 1 second, so the stunning voltage used for subsequent deer was changed instead to 400 volts which was the upper limit of the stunning devices capacity.

Materials and Methods

Animals

Thirteen fallow deer castrates aged 16 months with an average HCW of 19.78 (SEM $\pm$ 0.48) were slaughtered at the UWSH abattoir in early April (autumn). The deer had been held at the UWSH research farm since birth and were maintained on a kikuyu based pasture over sown with oats and ryegrass for winter feed. The deer had been yarded and handled approximately 3 times since birth for weaning, weighing and vaccination.

Slaughter Treatment

The deer were yarded at noon the day before slaughter and held overnight in the abattoir yards. They were without food or water for approximately 19 hours prior to slaughter. The deer were electrically stunned using 400 volts for a duration of either 1 or 3 seconds. The deer were exsanguinated using the gash cut technique approximately 8 seconds after stunning.

Measurements

Peak current at stunning was recorded. Carcasses were graded for ecchymosis using the boning room method previously described. Deer were observed at stunning to determine that the stun induced a typical tonic phase reaction.

Statistical Analysis

Using the total of the loin and round ecchymosis scores for each carcass, those with a score greater than 1 were considered 'affected' by ecchymosis, and those less than or equal to 1 'not affected'. Data regarding 'affected' and 'not affected' carcasses were analysed using the Chi squared test (Minitab 9, 1995).

Results

One deer was stunned at 100 volts for 1 second. The peak current recorded was 0.09 amps. The deer did not exhibit the typical tonic phase reaction indicative of a successful stun as previously described, rather it appeared to be fully conscious and exhibited signs of distress. It was immediately stunned again using a captive bolt. The ecchymosis score from the carcass of the deer were excluded from the analysis. The deer stunned using 100 volts for 1 second (0.09 amps), not included in Table 5.2, did not exhibit any ecchymosis.

When only those carcasses with a total loin and round ecchymosis score greater than 1 were considered affected by ecchymosis there was a significant treatment effect shown ($p < 0.01$), with the incidence of ecchymosis being least when the deer were stunned for the longer duration of 3 seconds. At 1 second duration the mean stunning current was 2.42 amps (SEM $\pm$ 0.32), and at 3 seconds duration it was 2.34 amps (SEM $\pm$ 0.15) (Table 5.2).

Table 5.2: Loin and round ecchymosis scores and peak stun currents for fallow deer stunned using 400 volts for either one or 3 seconds duration.

Stun current duration (sec.)	Peak stun current (amps.)	Loin and round ecchymosis scores				
		Total	loin		round	
			Left	Right	Left	Right
1	1.02	**12**	3	3	3	3
1	3.5	**8**	2	4	1	1
1	1.82	**5**	1	2	1	1
1	2.41	**5**	2	1	1	1
1	2.31	**4**	1	1	1	1
3	2.32	**1**	0	0	0	1
3	2.88	**1**	0	1	0	0
3	2.32	**1**	0	0	0	1
1	2.68	**0**	0	0	0	0
1	3.23	**0**	0	0	0	0
3	2.08	**0**	0	0	0	0
3	2.08	**0**	0	0	0	0

Discussion

The results suggest that head only electrical stunning using 100 volts for 1 second was not sufficient to stun fallow deer. This would suggest that stunning using 70 volts for 1 second as reported by Grogan (1998) would not have induced a tonic phase reaction and with respect to ecchymosis in fallow deer this should be taken into account when interpreting the results. Commercially, such a situation would be considered inappropriate on animal welfare grounds, and should not be allowed to occur at a commercial slaughter premises.

The results of the current study would indicate that ecchymosis in fallow deer may be reduced by increasing the duration of the stun current from 1 second to 3 seconds when using 400 volts. This was in contrast to observations in pigs (Lambooy and Sybesma, 1988) whereby a lower incidence of ecchymosis occurred in pigs stunned using 475 volts for 3 seconds, as opposed to those stunned using 70 volts for 10 seconds. From this it would appear that both voltage and stun current duration may interact to have an effect on ecchymosis expression.

Four separate consignments of deer were slaughtered at the UWSH abattoir in late winter (trials 1 and 2), and spring. Details pertaining to numbers, month of slaughter, sex type, and live weight range for the deer used in each trial are shown in Table 5.3.

Table 5.3: Number, sex type, month of slaughter, and live weight for deer used in experiments investigating the effect of voltage and duration on ecchymosis.

Trial	Date of slaughter	Sex type	n	Mean live weight (SEM $\pm$	Live weight range
1	August	Castrate	25	37.4 (0.37)	34.5 - 41.0
2	August	Castrate	22	47.6 (1.48)	40.0 - 63.5
3	October	Bucks	25	50.8 (1.83)	37.0 - 66.0
4	November	Does	23	47.8 (0.73)	42.0 - 53.5

The deer slaughtered in trial 1 were of the same age, approximately 20 months, as reflected in the similarity between their live weights, and all originated from the same farm. They were not yarded or handled until approximately 14 months of age when they were removed from the mob containing their mothers and castrated after removal of hard antler. One month later they were sold and transported to another farm where they remained for two months prior to being moved to the UWSH research farm. The deer were then maintained at the UWSH farm on a kikuyu based pasture over sown with oats and ryegrass. On alternate days they were also provided with approximately 1 kg of barley per head, to supplement the pasture feed supply. The deer were slaughtered one month after arrival at the UWSH farm. An attempt was made to collect blood from the deer via jugular venepuncture upon arrival at the UWSH farm. However, this was aborted due to excessive aversive behaviour shown by the deer to what would normally be consider routine handling procedure. The aversive behaviour to routine handling was observed to be considerably less upon yarding prior to slaughter and so blood was collected and the deer were weighed and ear tagged. This less aversive behaviour was perhaps reflective of a gradual habituation to human contact established as a result of the supplementary feeding regime.

The castrates and bucks slaughtered in trials 2 and 3 respectively, were acquired from two different farms. The deer from each farm were mixed during loading for transport to the UWSH farm so the exact source of each deer could not be determined. It was known that each of the farms had contributed deer of each sex type to the consignment. Upon arrival at the UWSH farm the deer were drafted into two mobs according to sex type and ear tags were replaced to enable individual identification. They were then maintained in the two separate mobs on a kikuyu based pasture and were provided with approximately 1 kg of barley per head every second day. Feed supplementation for both mobs ceased two days prior to the slaughter of the first mob. The deer arrived at the UWSH farm in the first week of August and the first of the consignment slaughtered were the castrates used in trial 2, conducted in the last week of that month. The bucks were slaughtered two months later in October. Neither of the mobs were yarded or handled until the day prior to slaughter when blood was collected via jugular venepuncture and deer were weighed. Prior to their arrival at the UWSH farm the deer had all been handled at least once as evidenced by all deer having been ear tagged and the bucks had hard antler removed.

The deer slaughtered in trial 4 came from a mob of 90 does of mixed ages that originated from the same farm. Upon arrival at the UWSH farm in mid September the entire mob was set-stocked on a kikuyu based pasture. The mob was yarded three weeks later and again the following week and 24 does were drafted off each time, weighed and then slaughtered the next day. The remainder of the mob went back to the same paddock. Trial 4 was conducted in the first week of November, after the does had been at the UWSH farm for six weeks. The does received no supplementary feed.

Slaughter Treatment

For each trial the deer were yarded at noon the day before slaughter and weighed. Blood was collected via jugular venepuncture from the castrates and bucks in trials 1, 2, and 3. With the exception of trial 1 in which the deer were held overnight in the abattoir yards, the deer remained overnight in the deer unit handling shed and were moved to the abattoir the following morning, a distance of approximately 180 metres. The deer had no access to food or water during the 20 hours prior to slaughter.

Within each trial, deer were allocated at random to one of twelve possible voltage and duration electrical stunning combinations comprising; 150, 200, 300 or 400 volts for one, two or 3 seconds. All deer were exsanguinated using the gash cut technique approximately 10 seconds after stunning.

In trial 1 attempts were made to stun two deer using 100 volts for 3 seconds. Peak currents of 0.12 and 0.27 amps were achieved. Neither of the deer exhibited the typical tonic phase reaction indicative of a successful stun, rather they appeared to be fully conscious and exhibited signs of distress. They were stunned again immediately with a captive bolt. On this basis no further attempts at stunning were made using 100 volts and these deer were excluded from the results.

Measurements

The peak stun current for each deer was recorded immediately after application of the current ceased. Stun voltage and duration were recorded as prescribed for each treatment group. Blood plasma was collected from castrates and bucks, as previously described, just after yarding at noon the day prior to slaughter, and again during exsanguination at slaughter. Circulating cortisol levels were determined from the samples taken on the day prior to slaughter and at slaughter. Circulating testosterone levels were only determined from the samples taken at slaughter. Heart rate was monitored for 10 seconds using a stethoscope just prior to stunning while the deer were held in the v-restrainer. The interval between the application of the stunning current and the cessation of the heartbeat was monitored using the stethoscope and recorded also. Carcasses were weighed just prior to chilling. The uterus of each doe was inspected at evisceration to determine pregnancy status.

Statistical Analysis

Each of the four trials was a completely randomised design and was analysed separately. The errors of the mean squares were compared, and as they were not different, the data from all of the trials was pooled into one combined analysis. This was a Randomised Complete Block (RCB) factorial design with the separate trials being the blocks. Using the total of the loin and round ecchymosis scores for each carcass, the data were square root transformed and analysed using analysis of variance (ANOVA) in Genstat 5, 4.1, (1997). The factors accounted for in the analysis included:

- live weight;
- HCW;
- voltage;
- voltage and duration;
- peak stun current;
- order of slaughter;
- circulating testosterone and cortisol levels, from bucks and castrates only, collected on the day before slaughter and at exsanguination;
- pre-slaughter heart rate; and
- the interval between stunning and the cessation of the heartbeat.

ANOVA (Minitab, 1995) was used to analyse the effect of voltage and duration on peak stunning current, and differences between trials with respect to heart rate prior to stunning and interval between stunning and heart cessation.

Results

Carcass Weights

The HCW range recorded for the castrates from trial 1 was 4.4 kgs in comparison with trials 2, 3, and 4 for which the ranges were 11.2 kgs, 14 kgs, and 17.5 kgs respectively. The ranges recorded for the latter three trials reflected significant age variations between the deer in each of those mobs particularly the bucks (trial 3) and castrates (trial 2) as was observed also with respect to the live weights presented earlier (Table 5.3).

Table 5.4: Number, sex type, month of slaughter, and HCW for deer used in experiments investigating the effect of voltage and duration on ecchymosis.

Trial	Date of slaughter	Sex type	n	Mean HCW (SEM ±)	HCW range
1	August	Castrate	25	22.1 (0.23)	19.9 - 24.3
2	August	Castrate	22	27.0 (0.87)	23.0 - 37.0
3	October	Bucks	25	29.1 (1.03)	21.5 - 39.0
4	November	Does	23	24.6 (0.60)	19.8 - 31.0

Electrical Stunning

All of the deer except those stunned using 100 volts and one deer on which the stunning probes were wrongly positioned, lapsed immediately into a tonic muscular spasm indicative of an epileptiform seizure associated with a state of insensibility.

The peak stun currents for the 400 volt, two and three second duration data sets show two uncharacteristically low recordings for that voltage of 0.82 and 1.03 amps (Figure 5.1). The peak stun current of 0.82 amps was from the deer mentioned earlier, whereby the stunning handset probes were applied to the dorsal surface of the neck approximately 6cm caudal to the ears rather than the normal position of less than 3cm from the ears. The peak stun current of 1.03 amps was from the first deer stunned with the modified stunning apparatus and was recorded approximately 10 seconds after the stun. The deer lapsed immediately into a tonic reaction. It was subsequently determined that the peak current recording shown on the monitor was generally only held for approximately 5 seconds after which time it began to diminish. All subsequent recordings were noted immediately upon the termination of the stunning current.

Figure 5.1: Peak stun currents recorded for voltages of 100, 200, 300, or 400 volts, applied for duration's of one, two, or 3 seconds, for the stunning of fallow deer.

Excluding the aforementioned data (0.82 and 1.03 amps), analysis showed voltage to significantly affect peak stunning current ($p < 0.001$) with the mean peak stun currents rising consecutively from 0.56 amps (SEM ± 0.39) at 150 volts to 2.75 amps (SEM ± 0.17) at 400 volts.

When voltage and duration combined were considered, a similar treatment effect occurred with the mean peak stun currents rising consecutively from the low of 0.5 amps (SEM ± 0.05) at 150 volts for 1 second, to a high of 3.09 amps (SEM ± 0.22) at 400 volts for 2 seconds, with a slight drop to 2.72 amps (SEM ± 0.25) at 400 volts for 3 seconds (Table 5.5). Within each duration, as voltage increased so to did the range of peak stun currents increase, and overall the range of peak stun currents for each voltage and duration combination also increased as reflected in the associated standard error of the means which went from ± 0.05 (150v, 1 sec.) to ± 0.25 (400v, 3 sec.) (Table 5.5).

Table 5.5: Peak stun currents recorded for stunning voltages and duration's, ranging from 150 volts for 1 second, to 400 volts for 3 seconds.

Stun voltage and duration. volts (seconds)	Number of deer slaughtered	Peak stun currents (amps.)				
		Mean	SEM ±	Minimum	Maximum	Range
150 (1)	8	0.501	0.052	0.36	0.72	0.36
150 (2)	7	0.559	0.053	0.40	0.80	0.40
150 (3)	8	0.628	0.090	0.39	1.13	0.74
200 (1)	8	0.909	0.112	0.47	1.32	0.85
200 (2)	8	1.023	0.122	0.47	1.44	0.97
200 (3)	6	1.090	0.194	0.49	1.93	1.44
300 (1)	8	1.636	0.225	0.52	2.44	1.92
300 (2)	8	2.170	0.185	1.18	2.82	1.64
300 (3)	8	2.368	0.169	1.55	3.03	1.48
400 (1)	8	2.925	0.207	1.66	3.67	2.01
400 (2)	7	3.087	0.223	1.99	3.91	1.92
400 (3)	5	2.726	0.250	2.20	3.50	1.30

Heart Function

The range of heart rates recorded during the 10 seconds prior to stunning was greater for the castrates from trials 1 and 2 at 123 and 113 beats per minute than those recorded for the bucks and does at 66 and 48 beats per minute. Comparing the data for each of the trials there was a significant ($p < 0.05$) difference observed between trials 2 and 4, with the mean heart rate being greater for the castrates from trial 2. Heart rates for trials 1 and 4 were similar to each other and between the rates recorded for trials 2 and 4 (Table 5.6).

Table 5.6: Heart rates (beats per minute) of fallow deer restrained in a v-restrainer recorded for a period of 10 seconds immediately prior to stunning.

Trial	Date of slaughter	Sex type	n	Mean heart rate (±SEM) (beats per minute)	Range (beats per minute)
1	August	Castrate	25	111.20 (5.60)	123
2	August	Castrate	22	122.50 (5.64)	113
3	October	Bucks	12	114.00 (5.27)	66
4	November	Does	21	102.57 (2.62)	48

The interval between stunning and the cessation of the heart beat was significantly ($p < 0.001$) longer for the bucks (trial 3) which recorded a mean interval of 172.5 seconds (SEM ± 14.4) compared with 102.55 sec. (SEM ± 4.93) and 88 sec. (SEM ± 2.38) for each of the castrate trials and 92 sec. (SEM ± 3.59) for the does.

Table 5.7: Length of interval between stunning and cessation of heart beat for fallow deer exsanguinated using the gash cut method of stunning approximately 8 seconds after stunning.

Trial	Date of slaughter	Sex type	n	Mean interval to heart cessation (± SEM) (seconds)	Range (seconds)
1	August	Castrate	22	102.55 (4.93)	96
2	August	Castrate	22	88 (2.38)	37
3	October	Bucks	6	172.5 (14.4)	73
4	November	Does	23	92 (3.59)	75

When the individual data for each animal were plotted according to either heart rate or interval between stunning and heart beat cessation, no relationships were observed between those factors and voltage, duration, peak stun current, liveweight, HCW, or circulating cortisol or testosterone levels.

Cortisol and Testosterone

Cortisol

Cortisol levels recorded on the day before slaughter showed the castrates from trial 1 to have higher levels overall than the other castrates and the bucks. However, while the mean cortisol level for the castrates from trial 1, at 105.7 *ng/mL* was only 14.9 *ng/mL* greater than the day before, for the castrates from trial 2, at 95.9 *ng/mL* the mean cortisol level at slaughter was 31.3 *ng/mL* higher. The mean cortisol levels recorded for the bucks did not differ significantly between the day before and at slaughter (+ 0.9 *ng/mL*) (Table 5.8).

Table 5.8: Circulating cortisol and testosterone levels in castrates and bucks recorded 20 hours prior to, and at slaughter.

Trial	Sex type	n	Cortisol (*ng/mL*)				Testosterone (*ng/mL*)	
			Day before		At slaughter			
				SEM ±		SEM ±		SEM ±
1	Castrate	25	90.8	3.9	105.7	5.3	0.48	0.02
2	Castrate	22	64.6	2.9	95.9	4.5	0.44	0.02
3	Buck	25	72.6	3.6	73.5	4.3	0.78	0.15

Testosterone

Two of the bucks recorded uncharacteristically high levels of circulating testosterone, 3.07 and 3.31 *ng/mL* and when these were excluded from the data the mean level was 0.56 *ng/mL* (SEM ± 0.02).

Relationship between Cortisol and Testosterone

When individual assay data for each of the trials comprising castrates and bucks was plotted according to testosterone levels there was no relationship to be observed between testosterone levels taken at slaughter and cortisol levels taken the day before, or at slaughter.

Order of Slaughter

The time taken to slaughter between 20 and 25 fallow deer at the UWSH abattoir was generally about 4 hours. When individual assay data was plotted according to order of slaughter for each of the trials no relationship to cortisol levels was observed.

Ecchymosis

As mentioned earlier, each of the four trials was analysed separately. The errors of the mean squares were compared and as they were not different the data from each trial were pooled into one combined analysis.

There was no significant treatment effect demonstrated between any of the factors accounted for in the analysis and the expression of ecchymosis, including:

- pre-stun factors (heart rate, cortisol, testosterone, live weight, HCW, order of slaughter);
- stun factors (voltage, voltage and duration, duration, peak stun current);
- post stun factors (duration of heart beat).

Table 5.9 shows the distribution of ecchymosis scores (loin and round totals) for each of trials 1, 2, 3, and 4, and Table 5.10 shows the same for all trial data combined.

Table 5.9: Distribution of total loin and ecchymosis scores for each of 4 trials investigating the effect of stun voltage and duration on the incidence of ecchymosis.

Ecchymosis score	Trial 1 (n = 25) castrates	Trial 2 (n = 22) castrates	Trial 3 (n = 25) bucks	Trial 4 (n = 23) does
0	1 *	1 *	1 *	2 **
1-2	4 ****	2 **	6 ******	3 ***
3-4	5 *****	6 ******	6 ******	6 ******
5-6	8 ********	3 ***	3 ***	2 **
7-8	4 ****	4 ****	3 ***	3 ***
9-10	1 *	2 **	4 ****	1 *
11-12	1 *	1 *	2 **	5 *****
13-14	1 *	2 **	0	1 *
15-16	0	1 *	0	0

Table 5.10: Distribution of total loin and ecchymosis scores for trials 1, 2, 3, and 4 combined, investigating the effect of stun voltage and duration on the incidence of ecchymosis.

Total loin and round ecchymosis score	Trials 1, 2, 3 and 4 (n = 95)
0	5 *****
1-2	15 ***************
3-4	23 ***********************
5-6	16 ****************
7-8	14 **************
9-10	8 ********
11-12	9 *********
13-14	4 ****
15-16	1 *

From the examination of the uterus from each doe in trial 4 it was determined that five of the does were not pregnant. The ecchymosis scores for these does were evenly distributed across the group (Grades 3, 5, 6, 11, and 12) indicating that pregnancy status did not affect ecchymosis expression.

The total loin and round ecchymosis scores, for each of the two deer unsuccessfully stunned using 100 volts for 3 seconds (0.27 and 0.12 amps) and subsequently stunned using a captive bolt were 7 and 5 respectively. Considering the distribution of ecchymosis scores shown for Trial 1, which was the group to which the deer belonged (Table 5.9) these scores could be considered unremarkable.

One of the deer stunned using 400 volts for 2 seconds recorded a current of 0.82 amps but did not lapse immediately into the tonic phase indicative of the grand mal seizure normally associated with a state of insensibility, and it was immediately stunned again with a captive bolt. The unsuccessful stun appeared to be due to operator error whereby the stunning handset probes were applied to the dorsal surface of the neck approximately 6cm caudal to the ears, rather than the normal position of less than 3cm from the ears. The total loin and round ecchymosis score for that deer was 8, which, when fitted into the data from Trial 2 (Table 5.9) where the deer came from, would also have been considered normal.

The overall incidence of ecchymosis observed in trials 1 to 4 was worse than in any mobs of deer slaughtered at a type B abattoir, which used the same stunning and exsanguination methods but with an interval between stunning and exsanguination of < 5 seconds, or a D1 abattoir which used a percussion stunner or .22 calibre firearm followed by gash cut exsanguination no less than 25 seconds later (Table 5.11).

Table 5.11: Left round ecchymosis scores for deer slaughtered commercially, and in trials 1 to 4 investigating the effect of stun voltage and duration on the incidence of ecchymosis.

Data source	Left round ecchymosis score					Number of carcasses	% of left rounds with score…	
	0	1	2	3	4		≥ 1	≥ 2
Trials 1 - 4	31	30	14	17	3	95	67	38
Type B abattoir	32	28	10	6	3	82	57	23
	85	7	1			93	9	1
	40	32	11			83	52	13
	54	3				57	50	0
	45	5				50	10	0
Type D1 abattoir	37	14	6	1		58	36	12
	9					9	0	0
	34	3	2			39	12	5
	8	6	3			17	53	18
	10	1				11	9	0

Discussion

Extending previous results, the current experiment showed that head only electrical stunning of fallow deer using 100 volts or less should not be used even with a stun current duration as long as 3 seconds. Using 150 volts, a stun current duration of 1 second was successful in inducing a tonic phase reaction in fallow deer thus suggesting the minimum voltage at 1 second duration to be somewhere between 100 and 150 volts. Further work could be conducted to clarify this however, as voltage was not shown to affect the incidence of ecchymosis in fallow deer such work would be of limited relevance to the current study.

A comparison between cortisol levels recorded the day before slaughter and at slaughter suggested a sex type difference between bucks and castrates with the castrates recording a higher mean level at slaughter than the day before, while the mean level for the bucks was similar at both times. Neither cortisol or testosterone levels within the range which occurred in the castrates or bucks slaughtered in the current trials were shown to affect ecchymosis expression and this result with respect to cortisol levels was consistent with the work of others in sheep (Pearson *et. al.*, 1977). Nor was heart rate prior to stunning observed to effect ecchymosis expression. With respect to both heart rate and blood plasma constituents it is possible that only levels higher or lower than those recorded in the current study may be associated with ecchymosis expression and hence it may only be possible to investigate the effect of pre-slaughter stress on ecchymosis expression by artificially manipulating the events indicated by these measures.

The results of a previous trial which showed stun current duration using 400 volts to have an effect on ecchymosis expression in a group of 12 deer of similar age, weight and pre-slaughter history was not repeated in the current experiment using groups of deer of mixed ages, weights or unknown pre-slaughter history. It would appear that on an individual animal basis certain deer in the less homologous groups used in the current study were affected more than others and this may have been related to factors unaccounted for in the trials. In addition to this, due to the experimental design there were relatively few deer associated with each voltage and duration combination and it is possible that larger numbers may be needed to account for individual animal differences.

The interval between stunning and the cessation of the heart was not affected by voltage or stun current duration and therefore should not be of concern with respect to Muslim slaughter.

5.4 Conclusions

The mean peak current (0.79 amps, SEM $\pm$ 0.02) recorded at the commercial abattoir was below the 1.0 or 1.3 amps used by Cook *et. al.* (1994a and 1994b) for the stunning of fallow deer, and the 1.0 amp put forward by Gilbert (1993) as the minimum required to render insensible red deer. However, in comparison with the present study where the stun duration used was 1 second, Cook *et. al.* (1994a) used only 0.1 seconds, which was not successful, and 0.2 seconds which was. The lowest peak stun current recorded at the commercial abattoir was 0.4 amps and at a duration of 1 second this current caused the deer to lapse immediately into a tonic muscular spasm indicating the successful initiation of an epileptiform seizure. This would suggest that the minimum currents put forward by others may have only been required due to the short duration of the current (0.2 seconds). When the duration was increased, as it was in the current study, 0.4 amps for 1 second was sufficient to cause an epileptiform seizure as indicated by the onset of a tonic phase reaction.

One of the deer stunned in the experiment investigating current duration, and two of the deer stunned in the trials investigating voltage and duration, did not lapse into a tonic phase as a result of the stun. The attempt to stun the first deer was made using 100 volts for 1 second which achieved a peak current of 0.09 amps, and the attempts on the other two were made using 100 volts for 3 seconds which achieved peak currents of 0.12 and 0.27 amps. These results would suggest that stunning using 70 volts for 1 second as reported by Grogan (1998) would not have caused the deer in that study to lapse into a typical tonic phase reaction. At the type B abattoir where the trial was carried out, the design of the slaughter system was such that shackling of the deer was not contingent on their immobilisation, as would usually occur with successful stunning. Hence, it is possible that the lack of a tonic phase being initiated by the stun may have either not caused concern, or it may have not been noticed. It is highly probable from observations in the current study that stunning at 70 volts would not have caused a state of insensibility in the deer. Such a situation would be considered inappropriate on animal welfare grounds, and should not be allowed to occur at commercial slaughter premises. The minimum voltage required to cause a tonic phase reaction indicative of an epileptiform seizure, appears to be greater than 100 volts, even at a duration of 3 seconds, but may be less than 150 volts when the duration of the stun current is 1 second.

One of the deer stunned using 400 volts for 2 seconds did not lapse immediately into a tonic phase reaction indicative of the grand mal seizure normally associated with a state of insensibility, although the current recorded was 0.82 amps. The unsuccessful stun was subsequently attributed to operator error, whereby the stunning handset probes were applied to the dorsal surface of the neck approximately 6cm caudal to the ears, rather than the normal position of less than 3cm from the ears. It would appear that regardless of the peak stun current delivered a successful stun may be contingent on the correct placement of the probes no more than 3cm caudal to the baseline of the ears.

All of the deer unsuccessfully stunned electrically were stunned again using a captive bolt. One deer had been stunned using 100 volts for 1 second, two deer using 100 volts for 3 seconds, and one deer using 400 volts for 2 seconds but with incorrect placement of the handset probes. The latter three deer all exhibited ecchymosis within the normal distribution of scores for the other deer in their trials. The deer stunned using 100 volts for 1 second exhibited no ecchymosis. While captive bolt stunning has been shown to reduce ecchymosis in comparison with electrical stunning (Spencer, 1979; Kirton *et. al.*, 1980; Grogan, 1998) from the current study, although based on limited numbers it would appear that captive bolt stunning subsequent to electrical stunning does not eliminate ecchymosis.

Lambooy and Sybesma (1988) found a higher incidence of ecchymosis in pigs stunned using 70 volts for 10 seconds in comparison with pigs stunned using 475 volts for 3 seconds. The results of the current study were in contrast to this with respect to both voltage and duration. The results of the current study showed voltage to have no effect on ecchymosis, and in the experiment investigating duration only it was found that stunning for the shorter duration of 1 second produced significantly ($p < 0.01$) more ecchymosis than stunning for 3 seconds. The result regarding ecchymosis incidence from the trial investigating stun duration was not repeated in the subsequent trials (1 to 4) investigating both voltage and duration. In interpreting the results from trials 1 to 4 however, it is important to recognise that little was known with regard to the pre-slaughter history of the deer used in those trials. There were clearly a considerable number of differences between trials and between individual deer, that were accounted for in the analysis, such as weight, sex type, pregnancy status, and hormone levels. However, there may also have been any number of other differences between the deer associated with the aforementioned differences, but not measured, that may have influenced the effect of stunning method on the expression of ecchymosis. The deer from the trial investigating duration only were born on the UWSH farm and were all similar in weight and age. In contrast, within each of the trials 2, 3, and 4, which investigated voltage and duration there were considerable differences in the age and weight of the animals used, and in trials 1, 2, 3, and 4 little was known about the history of the deer prior to their arrival at the UWSH research farm. Considering the variability between individual deer used in trials 1 to 4 the number of deer able to be allocated to each stun treatment group was small, and this may have contributed significantly to the results. In order to accommodate for the diversity of biological and behavioral characteristics within groups of deer, either deer of known homogeneity or larger numbers of deer may need to be used to investigate some factors associated with ecchymosis in this species.

The results from the trials investigating both voltage and duration showed that as stun voltage and duration increased so too did the peak stun current increase from a mean of 0.56 amps (SEM $\pm$ 0.39) at 150 volts to 2.75 amps (SEM $\pm$ 0.17) at 400 volts. As mediated by voltage and duration peak stun current was observed to have no effect on the expression of ecchymosis. For this reason, with respect to reducing ecchymosis there would be no advantage in using current rather than voltage-controlled devices.

The incidence of ecchymosis in the current study was considerably higher than that recorded in any mobs slaughtered at commercial type B and D1 abattoirs. In trials 1 to 4 collectively 67 % of the left rounds exhibited ecchymosis greater than grade 0 and 38 % greater than grade 1. Of the 365 left rounds scored at the type B abattoir 29% exhibited ecchymosis greater than grade 0 and only 8% greater than grade 1. Of the 134 rounds scored at the type D1 abattoir 27% exhibited ecchymosis greater than grade 0 and 9% exhibited ecchymosis greater than grade 1. A number of factors may have contributed to this difference including; the different intervals between stunning and exsanguination, which was 8 seconds or more at the UWSH abattoir, but less than 5 seconds at the commercial type B abattoir, or the method of stunning which was head only electrical in the current study in comparison with captive bolt at the type D1 abattoir. Both stunning method, and the interval between stunning and exsanguination, are investigated further in subsequent sections.

The voltage used at the type B abattoir from which case study data was obtained was maintained at 150 volts or less due to the perception of the resident Muslim slaughterman that greater voltages would cause the heart to stop beating sooner than lower voltages. The results from the current experiments showed that neither voltage or duration had any effect on the duration of the heart beat from stunning and the use of higher voltages in this respect does not compromise Muslim slaughter. Furthermore, the duration of the heartbeat after stunning was shown not to have any effect on ecchymosis expression. Interestingly, of the six bucks for which heartbeat duration was recorded, three recorded duration’s of just over 200 seconds and the other three recorded duration’s of approximately 140 seconds. This was in contrast to the maximum duration’s of 150, 125, and 110 seconds for each of the other trials. Given that the exsanguination method and duration between stunning and exsanguination was the same in all trials, this perhaps indicated a sex effect.

Heart rate prior to stunning ranged from 63 to 190 beats per minute overall and within that range heart rate was shown to have no effect on ecchymosis expression. While the minimum heart rate recorded for all trials was between 63 and 84 beats per minute, the maximum recorded for each group of castrates was approximately 190 beats per minute, while only 140 beats per minute for each of the doe and buck groups. Again this may have indicated a sex difference.

The mean cortisol levels recorded for the castrates and bucks slaughtered in the trials investigating voltage and duration were higher than those recorded by Pearson *et. al.* (1977) in lambs slaughtered at large and small abattoirs. The mean cortisol levels for the deer slaughtered in trials 1, 2, and 3 were 105.7, 95.9, and 73.5 *ng/mL*, in comparison with the mean levels for lambs of 61.3 and 40.1 *ng/mL* slaughtered at large and small abattoirs respectively. The variation from the mean for all deer and sheep trials were similar however, with 26.5, 21.2, and 21.6 *ng/mL* recorded for the deer, and 26.1 and 23.7 *ng/mL* recorded for the two groups of lambs. Cortisol levels from the current study were also consistent with those observed in other trials conducted at the UWSH abattoir. The observation of Pearson *et. al.* (1977) that cortisol levels within the ranges recorded for each of two groups of lambs showed no relationship to ecchymosis expression, is consistent with the results of the current study.

It would appear that varying the voltage used for the head only electrical stunning of fallow deer would have no effect on reducing the incidence of ecchymosis. It is possible however, that in homologous groups of deer, varying the duration of the stun current may help to reduce ecchymosis incidence. On the basis of animal welfare, more detailed studies, using EEG recordings, should preclude the use of voltages of less than 150 volts for 1 second, for the head only electrical stunning of fallow deer, even at stun duration's of 3 seconds. Clearly, any number of individual animal variations may affect the influence of slaughter method on ecchymosis expression, and these need to be accounted for in the design of experiments by either; using deer of considerable homogeneity only, or treatment groups larger in number than those used in the current study. However, the commercial reality is that deer from different backgrounds, and of different sexes and sizes may arrive at a slaughter premise on the one day, and these variations are unlikely to be accommodated by the slaughterman on duty. Hence the recommendation for voltages of no less than 150 volts for 1 second or longer.

6. The effect of method of exsanguination on ecchymosis in electrically stunned fallow deer

6.1 Introduction

In pilot studies on rates of blood loss, the thoracic stick method of exsanguination was shown to cause a greater rate of blood loss than the gash cut method of exsanguination, regardless of the method of stunning which preceded exsanguination. While the rates of blood loss attributed to the various combinations of stunning and exsanguination methods were discussed the relationships between the exsanguination methods and the incidence of ecchymosis were not examined.

At the commencement of this study (1996) most fallow deer in Australia were slaughtered for export at a type B abattoir, the only export abattoir available for processing fallow deer from Queensland, NSW, Victoria and South Australia at the time. All of the fallow deer slaughtered at that abattoir were electrically stunned and exsanguinated using the gash cut method. During the case study investigations reported previously, there were a number of reports of difficulties with ecchymosis from venison processors that had previously used other type B abattoirs that employed the same slaughter system except for the exsanguination method. At one of these abattoirs, only the thoracic stick method of exsanguination was used, and at the other, the gash cut method was followed shortly after by the thoracic stick method of exsanguination for each animal. Neither of the processors who used the thoracic stick method considered ecchymosis in fallow deer to be a problem, citing estimated incidences of only 1%. One of these processors had introduced the use of the thoracic stick method of exsanguination after encountering a significant number of carcasses with ecchymosis. He believed the thoracic stick method had reduced the incidence of ecchymosis, although the abattoir ceased killing deer too soon after to be more certain. At another type B abattoir which reported a low incidence of ecchymosis in fallow deer carcasses, the Muslim slaughtermen did not object to the tying of the oesophagus, otherwise known as weasand tying, occurring immediately after gash cut exsanguination. Weasand tying involved a caudo-cranial incision of the neck, often followed by another incision up into the thoracic cavity to expose the oesophagus and trachea. A special tool was then used to detach the esophagus from the adjacent muscles and trachea, enabling it to be tied to prevent the escape of rumen contents. Observations of this practice at a small domestic abattoir showed that a release of blood from the thoracic cavity occurred as a result of weasand tying, which was similar to that seen using the thoracic stick method of exsanguination.

No previous work has compared the effect of the thoracic stick and gash cut methods of exsanguination on the incidence of ecchymosis in fallow deer, or any other livestock species slaughtered for meat. It could be postulated that the thoracic stick method of exsanguination would be associated with a lesser incidence of ecchymosis, due to the more immediate relief from elevated blood pressure associated with the stun. Kirton *et. al.*. (1978) determined that reducing the interval between stunning and exsanguination was associated with a reduction in the severity of ecchymosis in lambs. They also showed that the shorter interval was associated with a more immediate drop in blood pressure.

The following experiment was designed to investigate the effect of the thoracic stick and gash cut methods of exsanguination on the incidence of blood splash in electrically stunned fallow deer slaughtered at a type B abattoir. It was not possible to measure the rates of blood loss associated with each slaughter method due to the speed at which the slaughter process was carried out. However, these were determined in other experimental trials, reported later in this report.

Materials and methods

Animals and pre-trial management

Trial 1: Twenty four eighteen month old fallow does were slaughtered in the middle of Spring. The does had not been mated and had previously been used in nutrition trials at the UWSH deer research unit. As part of that trial the deer had been weighed fortnightly and were therefore well habituated to yarding and handling. The does had been paddock grazed on a kikuyu based pasture over sown with oats and ryegrass in Autumn to provide winter feed. The does were not weighed prior to slaughter in order to reduce the amount of pre-slaughter handling they were subjected to. The mean HCW of the does was 20.2 kgs (SEM $\pm$ 0.58).

Trial 2: Twenty four fallow bucks aged approximately twenty months or older were slaughtered in the last month of Summer. The bucks had been paddock grazed on a kikuyu based pasture over sown with oats and ryegrass in Autumn to provide winter feed. Unlike the does in trial 1, the bucks had not been used in any previous research and had only been subjected to a normal handling regime associated with general animal husbandry practices. This comprised being weighed occasionally, ear tagging, and velvet antler removal. In total, the bucks would have been handled approximately 4 times in their 20 months. The bucks were not weighed prior to slaughter in order to reduce the amount of pre-slaughter handling they were subjected to. The mean HCW of the bucks was 23.1 kgs (SEM $\pm$ 0.49).

Pre-slaughter Management

The deer were yarded at noon on the day prior to slaughter, loaded into a fully enclosed trailer designed especially for carrying fallow deer, and transported to a type B abattoir approximately three hours away. The deer were held in lairage overnight at the abattoir, and had no access to food or water from the time of yarding until slaughter, a period of approximately 18 hours.

Slaughter Method

All deer were head only electrically stunned using 400 volts for a duration of 1 second. This was in contrast to the usual application of between 100 and 150 volts for 1 second observed by the author during previous visits to the abattoir, and the 70 volts reported by Grogan (1998) to have been used on fallow deer at the same abattoir on a previous occasion. Given the experimental nature of the exsanguination procedure, the higher voltage was assigned in order to minimize the risk of an animal recovering from the stun, should the thoracic stick method have delayed the onset of cerebral anoxia. Half of the deer in each trial (n=12) were exsanguinated using the thoracic stick method of exsanguination by one of the authors (Falepau), with the other half exsanguinated by the Muslim slaughterman, using the gash cut technique.

Order of Treatment

Due to the design of the slaughter system the order of the sticking treatments could not be randomised. To account in part for any effect that the order of kill may have had on the results, the first twelve deer in trial one and last twelve deer in trial two were bled using the gash cut exsanguination method. This also enabled the resident slaughterman to observe the thoracic stick exsanguination in the second trial. The treatment groups were not held in separate pens prior to slaughter and no attempt was made to influence the order in which the individual deer were presented for slaughter.

Participative Approach

The current study comprised four phases, the first of which involved a researcher visiting the abattoir to become known to the management and staff and discuss the project. On this visit the researcher met especially with the resident Muslim slaughterman and observed him slaughtering fallow deer.

The second phase involved the first of the slaughter trials with the inclusion of the slaughterman whereby he exsanguinated all the deer allocated to the gash cut treatment group. At the conclusion of the first trial the slaughterman was asked the following question and on the basis of his reply the second trial was designed:
Question 1: "If the results from boning out the carcasses show the deer you [slaughterman/gash cut] slaughtered have more ecchymosis than the ones I [researcher/thoracic stick] did would you be prepared to use my way [thoracic stick]",
Reply: "No because it's not the right way. It cuts the heart. It stops the heart."

The third phase involved the second deer slaughter trial where the slaughterman once again exsanguinated all the deer allocated to the gash cut treatment group. The results from trial 1 had shown a highly significant treatment effect on ecchymosis with the thoracic stick treatment group having the lower incidence. This was expressed to the slaughterman prior to the commencement of the second trial. Using a stethoscope a research assistant monitored the duration of the heart beat of a number of the deer from the thoracic stick treatment group subsequent to the initiation of exsanguination. The deer from the thoracic stick treatment group were slaughtered first in the second trial so the Muslim slaughterman was free to observe the monitoring of the heart beat. It was not possible to interview the slaughterman after the trial was completed.

The fourth phase involved another visit to the abattoir where the slaughterman was interviewed and asked whether the thoracic stick method of exsanguination could now be implemented given that the results of the second trial showed the duration of the heart to continue for at least 28 seconds and none of the hearts had been severed using the technique.

Measurements

Ecchymosis was scored using the boning room method (see general materials and methods). Approximately half of the hearts from the deer exsanguinated by the thoracic stick method were examined post mortem for incisions, and the heart beat was monitored using a stethoscope in 7 of the bucks exsanguinated by the thoracic stick method.

Statistical Analysis

Total ecchymosis score data were analysed using ANOVA (Minitab 9, 1995) to determine slaughter treatment effect on ecchymosis expression.

Results

Both trials showed a highly significant ($p < 0.001$) slaughter treatment effect on ecchymosis expression in the rounds and loins of the deer, with the gash cut method causing a greater amount of ecchymosis than the thoracic stick method of exsanguination (Table 6.1). Combining the data from both trials, the mean total ecchymosis score was 4.29 (SEM $\pm$ 0.72) for the gash cut treatment group and 0.46 (SEM $\pm$ 0.32) for the thoracic stick treatment group.

Comparing the ecchymosis scores for the carcasses affected by ecchymosis only showed a significant difference ($p = 0.02$) between trials with a mean total ecchymosis score of 6.73 (SEM $\pm$ 0.99) for the does (n= 11) and 4.00 (SEM $\pm$ 0.47) for the bucks (n= 10).

Table 6.1: Skeletal muscle ecchymosis scores for does and bucks exsanguinated by either gash cut or thoracic stick methods at a type B abattoir.

	Exsanguination method									
Trial and sex type	Gash cut					Thoracic stick				
	Ecchymosis scores					Ecchymosis score				
	Left loin	Right loin	Left round	Right round	**Total**	Left loin	Right loin	Left round	Right round	**Total**
Trial 1 Does	2	1	2	2	**7**	0	0	0	0	**0**
	4	3	3	4	**14**	0	0	0	0	**0**
	2	1	1	0	**4**	0	0	0	0	**0**
	3	2	2	1	**8**	0	0	0	0	**0**
	2	2	3	2	**9**	0	0	0	0	**0**
	2	1	1	1	**5**	0	0	0	0	**0**
	1	0	2	2	**5**	0	0	0	0	**0**
	2	2	2	3	**9**	0	0	0	0	**0**
	2	1	2	2	**7**	0	0	0	0	**0**
	0	1	1	2	**4**	0	0	0	0	**0**

	Exsanguination method									
Trial and sex type	Gash cut					Thoracic stick				
	Ecchymosis scores					Ecchymosis score				
	0	0	0	0	**0**	0	0	0	0	**0**
	1	0	1	0	**2**	0	0	0	0	**0**
	Carcasses affected = **11**					Carcasses affected = **0**				
Trial 2 Bucks	2	2	0	0	**4**	0	0	0	0	**0**
	1	0	0	0	**1**	0	0	0	0	**0**
	0	0	0	0	**0**	0	0	0	0	**0**
	0	0	0	0	**0**	0	0	0	0	**0**
	1	2	1	1	**5**	0	0	0	0	**0**
	1	1	1	1	**4**	0	0	0	0	**0**
	1	1	1	1	**4**	0	0	0	0	**0**
	2	1	1	1	**5**	0	0	0	0	**0**
	1	1	0	0	**2**	0	0	0	0	**0**
	1	1	1	1	**4**	2	2	0	1	**5**
	0	0	0	0	**0**	2	2	1	1	**6**
	0	0	0	0	**0**	0	0	0	0	**0**
	Carcasses affected = **8**					Carcasses affected = **2**				

The mean interval between the initiation of exsanguination to the absence of a heart beat, recorded in the bucks exsanguinated by the thoracic stick method (n= 7) was 48.6 seconds (SEM $\pm$ 5.2), with the minimum duration being 28 seconds. None of the hearts removed and inspected from the deer exsanguinated by the thoracic stick method exhibited any incisions.

From the second phase of the participative approach, the reasons expressed by the resident Muslim slaughterman against the use of the thoracic stick method of exsanguination should it have proved to reduce ecchymosis were; "…because its not the right way. It cuts the heart. It stops the heart."

During the final interview with the slaughterman the results of the second trial were discussed including; those pertaining to the inspection of the hearts, the effect of the exsanguination method on ecchymosis incidence, and monitoring of the heart beat with which he had previously been involved. The reason put forward in the final interview against the adoption of the thoracic stick method of exsanguination was "Its not the Halal way." The use of a thoracic stick incision immediately after the gash cut or the more immediate tying of the weasand were also discussed. These permutations were also deemed not able to be implemented on the grounds that they would constitute someone else having killed the animal.

Discussion

In a previous study Kirton *et. al.* (1978) compared ecchymosis in lambs gash cut immediately before electrical stunning, immediately after electrical stunning, and 5 to 8 seconds following stunning. The incidence of ecchymosis associated with each of the treatments was found to increase respectively. This led Kirton *et. al.* (1978) to suggest that while the application of the electrical current led to the damage of small blood vessels prior to the elevation of blood pressure, further leakage of blood from those vessels was exacerbated by prolonging the interval between stunning and exsanguination, and consequent blood pressure release.

It was determined that the thoracic stick method of exsanguination caused greater blood loss within 10 seconds of the initiation of exsanguination than the gash cut method. On that basis it may be expected that the thoracic stick method of exsanguination also caused a more immediate release of blood pressure, previously elevated by the stun, than the gash cut method. Consequently, if there was an association between the interval between stunning and exsanguination, blood pressure and the incidence of ecchymosis the thoracic stick method of exsanguination should have also resulted in a lower incidence of ecchymosis. From the results of this experiment this was the case, with a significantly lower incidence of ecchymosis observed in the carcasses of the deer exsanguinated using the thoracic stick method than those exsanguinated by the gash cut method.

The participative approach enabled the identification of barriers to the implementation of alternative methods of slaughter with the potential to reduce the prevalence of ecchymosis in fallow deer. In the current study the initial reasons for not adopting the thoracic stick method of exsanguination were expressed by the intended user in relatively technical terms, perhaps the only way the slaughterman perceived he could communicate with the researcher. Subsequent to the researcher invalidating by empirical measurement the basis behind the initial reasoning, the reason was restated in cultural terms only; “It is not the Halal way”. It was apparent that from the perspective of the Muslim slaughterman, the validity attached to some 1000 years of tradition outweighed the validity attached to empirical scientific methodology. The adoption of alternative methods for ritual slaughter would require a more substantial investigation into the basis behind the use of current practices and negotiation with the relevant religious authorities.

The participative approach used in the current study did not involve all four stages advocated in the “Farmer first Farmer last” model (Chambers and Ghildyal, 1985) discussed earlier. Rather, the current study involved only the adaptation and testing (stage 3), and farmer evaluation stages (stage 4). Contrary to the diagnosis of the problem by the farmer and researcher (stage 1), ecchymosis in fallow deer had been identified as a problem by the researcher and some venison processors, but it was not diagnosed as a problem in conjunction the with slaughterman. The apparent likelihood of the slaughterman wishing to reduce ecchymosis was negligible. In brief, ecchymosis in fallow deer was not his problem and at the abattoir in which he worked, not reducing it did not threaten his livelihood. Contrary to potential solutions being sought from multidisciplinary sources (stage 2 of the model) only those of a technical nature were considered in the current study. This was in part a manifestation of not having included the slaughterman in stage 1 whereby the cultural dimension of the slaughter process may have been recognised and alternative solutions considered.

While it is apparent that the use of the participatory approach to research and development advocated by Chambers and Ghildyal (1985) in their model “Farmer first Farmer last”, may be of greater benefit if all stages of the process are used, it was also observed to be of some benefit to the current study when used in part. The inclusion of the slaughterman in the testing of the alternative technology enabled the strongest barrier against its adoption to be determined and this should be considered by venison processors when contemplating the merits of alternative markets for their venison. The continual contact with the type B abattoir required for the participatory approach also enabled the attitude of the management and staff toward reducing venison defects to be assessed. In brief, although cooperation was pledged by management and various staff of the abattoir on each occasion, where face to face contact was made by the researchers, no cooperation was forthcoming. This also may be taken in to consideration by venison processors contemplating the merits of various commercial slaughter facilities.

In the current study, the gash cut and thoracic stick methods of exsanguination were only tested in conjunction with electrical stunning. Considering the proposition of Kirton *et. al.* (1978) that the application of the electrical current led to the damage of small blood vessels prior to the elevation of blood pressure, it is possible that a further reduction in the incidence of ecchymosis may occur if captive bolt stunning was to precede the thoracic stick method of exsanguination, rather than electrical stunning. The effects of stunning and slaughter combinations on the incidence of ecchymosis are investigated in a later section of this report.

The current experiments indicated a significant difference between trials in the severity of the ecchymosis exhibited in the affected carcasses. The ecchymosis exhibited in the does was more severe than that exhibited in the bucks. Given that both trials were carried out at the same abattoir the most marked differences between the trials were the sex of the animals slaughtered, and the fact that the first twelve does and last twelve bucks, were exsanguinated using the gash cut. It is possible that the deer in the treatment group slaughtered first in each trial were the most susceptible to ecchymosis, and the deer in the second treatment group less susceptible, because of some physiological difference associated with the order in which they presented themselves for slaughter. However, this remains conjecture. It is also possible that sex type had an effect on the expression of ecchymosis. The relationship between sex type and pre-disposition to ecchymosis was explored further in a later section. In brief, castrates were 9.8 times more likely to have ecchymosis than bucks, and does 4.2 times more likely. This would suggest sex type to be a valid explanation for the difference in ecchymosis between the trials in the current study.

The results from the current experiments tend to substantiate anecdotal reports received from processors that the use of the thoracic stick method, or permutations thereof, reduce the incidence of ecchymosis in the commercial situation. Based on the results from these experiments, the thoracic stick should be incorporated where possible into slaughter systems for fallow deer.

6.2 The effect of incomplete severance of the neck during ritual slaughter

Previous experiments investigated the rates of blood loss associated with the gash cut and thoracic stick methods of exsanguination, and the effect of these two methods on the incidence of ecchymosis. In those trials of the rate of blood loss induced by the thoracic stick exsanguination method was greater than that induced by the gash cut technique, regardless of the stunning method employed. The thoracic stick exsanguination method to be associated with a significantly lower incidence of ecchymosis when compared with the gash cut technique, in fallow does and bucks slaughtered in Spring and Summer respectively, at a type B abattoir.

At one of the type D abattoirs reported in the case studies, the design of the stunning and exsanguination area was such that the slaughterman, who was right handed, was positioned on the wrong side of the recumbent animal to effectively implement a gash cut 100% of the time. Often a number of attempts were required to completely sever both common carotid arteries and jugular veins. This human error clearly had the potential to reduce the rate of blood loss, and sustain the elevated blood pressure induced by the stun, which had previously been associated with an increased incidence of ecchymosis.

The current experiment was designed to investigate the relationship between the incomplete severance of the neck and the incidence of ecchymosis. The study also contributed comparative data for on rates of blood loss and Chapter on circulating testosterone and cortisol concentrations associated with slaughter and sex type.

Materials and methods

Animals

Twelve fallow bucks aged over 2 years were slaughtered in the trial in later summer (February). The bucks had been at the University of Western Sydney - Hawkesbury (UWSH) deer research and teaching unit for 8 months as part of a larger mob and 3 months together as the slaughter mob, prior to slaughter. The bucks were handled once upon arrival at the deer unit and twice thereafter for weighing and drafting. The bucks were maintained on kikuyu based pasture, over sown with oats and ryegrass for winter feed. The bucks were not weighed prior to slaughter in order to minimise pre-slaughter stress. Mean HCW was 27.5kgs (SEM $\pm$ 0.4).

Lairage

The bucks were yarded at noon the day before slaughter and held overnight in the abattoir yards. Upon yarding the bucks were initially separated into three mobs. However, this caused excessive fighting amongst the bucks as they presumably attempted to re-establish a social hierarchy within each smaller group. The three mobs were subsequently joined together again and fighting was reduced. The deer had no access to food or water during the 20 hours prior to slaughter.

Slaughter Treatment

The bucks were assigned to either of two treatment groups, one of which involved the complete severance of both common carotid arteries and jugular veins being the conventional gash cut method previously described. The second treatment involved severing only the left common carotid artery and jugular vein. The bucks were stunned using 400 volts for 1 second and the mean peak current recorded was 3.26 amps (SEM $\pm$ 0.1). Deer from the latter group were captive bolt stunned after 20 seconds to prevent a return to consciousness. This was considered more than sufficient given that the minimum time till return to consciousness after head only electrical stunning at 1.3 amps for 0.2 seconds was approximately 60 seconds with out exsanguination (Cook *et. al.*, 1994a).

Measurements

Weight of blood lost from each animal for 10 seconds subsequent to the initiation of exsanguination was measured by collecting all blood into plastic garbage bags. Blood samples were collected from each animal at the time of exsanguination and circulating cortisol and testosterone concentrations were determined as described in the general methods. Ultimate pH of the M longissimus dorsi was measured after 20 hours using a standard pH meter which compensated for temperature (TPS LC80-A, Jenkins, Queensland, Australia). Carcasses were also inspected for bruising. Carcasses were scored for ecchymosis using the boning room method previously described. The interval between the initiation of exsanguination and the cessation of heart function was monitored using a stethoscope.

Statistical Analysis

Blood loss and heart function data was analysed for treatment effect using ANOVA (Minitab 9, 1995). No statistical analysis was required to determine treatment effect on ecchymosis.

Results

A highly significant (p= 0.004) treatment effect was observed with respect to the weight of blood lost during the 10 seconds subsequent to exsanguination from the deer from each treatment group. The mean weight of blood collected from the deer in which only the left jugular and carotid veins of the neck were severed was 178.1 grams (SEM $\pm$ 11.6) in comparison with 347.8 grams (SEM $\pm$ 44.3) for the complete gash cut group (Table 6.2).

Slaughter treatment also had a significant effect (p= 0.02) on the length of the interval between the initiation of exsanguination and the cessation of heart function. Heart function generally ceased earlier in the deer from the complete gash cut treatment group with a mean interval of 104.50 seconds (SEM $\pm$ 3.96) than in the deer whose necks were not completely severed, which had a group mean interval of 131.50 (SEM $\pm$ 8.95).

Table 6.2: Skeletal muscle ecchymosis scores and data from fallow deer exsanguinated by complete or incomplete severance of the neck.

Slaughter treatment	Ecchymosis scores				Blood lost (grams)	pH	Heart duration (seconds)	Cortisol (*ng/mL*)	Testosterone (*ng/mL*)
	Left loin	Right loin	Left round	Right round					
Complete gash cut (2 sides)	4	4	2	1	529.3	6.22	89	81.11	0.83
	2	1	0	2	319.5	6.51	117	103.69	0.81
	0	1	1	2	263.5	6.51	109	62.06	3.61
	0	0	1	2	227.7	6.54	98	74.73	2.69
	0	1	1	0	339.0	6.42	107	66.80	1.09
	0	0	0	0	407.8	6.60	107	83.25	0.95
	Carcasses affected = 5								
Incomplete gash cut (1 side)	1	3	3	0	229.1	6.01	142	101.54	0.66
	1	0	0	1	166.7	6.28	135	95.12	1.31
	0	1	0	0	164.5	5.98	96	57.78	0.77
	0	0	1	0	193.4	6.81	143	101.18	1.44
	1	0	0	0	152.4	6.37	116	122.77	2.23
	0	0	0	0	162.6	6.27	157	62.43	1.38
	Carcasses affected = 5								

There was no treatment effect on the incidence of ecchymosis apparent with five out of six carcasses exhibiting ecchymosis in each treatment group, nor was any treatment effect on ultimate pH observed. The mean ultimate pH was 6.38 (SEM 0.07).

When individual assay data was plotted according to circulating testosterone or cortisol levels no relationship between these hormone levels and ecchymosis, or slaughter treatment was observed. The mean circulating cortisol and testosterone concentrations were 84.37 *ng/mL* (SEM $\pm$ 5.93) and 1.48 *ng/mL* (SEM $\pm$ 0.26) respectively.

Post mortem examinations revealed considerable bruising in 9 of the 12 carcasses. However, these were not exclusive to a treatment group.

Discussion

The incomplete severance of the neck, which left the carotid artery and jugular vein on the right side of the neck intact, resulted in a lower weight of blood lost in the 10 seconds subsequent to the initiation of exsanguination than the conventional gash cut method of exsanguination. However, a treatment effect was not observed with respect to the incidence of ecchymosis in the skeletal muscles of the carcass. In previous experiments, the thoracic stick method of exsanguination was observed to significantly reduce ecchymosis in comparison with the gash cut method and it was proposed that this was due to the greater rate of blood loss associated with the former of the two methods. From the current experiment it is apparent there may be a number of factors associated with the thoracic stick method reducing the incidence of ecchymosis other than the rate of blood loss per se. In the current experiment the significantly lower rate of blood loss associated with the incomplete gash cut was not reflected in an increase in ecchymosis. That the same effect on ecchymosis observed between the thoracic stick and gash cut methods was not observed in the current experiment, despite a similarly significant difference in rates of blood loss is possibly a manifestation of the different sites of incision associated with the various methods. The thoracic stick method released blood from the region of the animal where blood volume was concentrated as a result of the stun. In contrast with both the complete and incomplete gash cut methods blood was still required to redistribute to the region of the neck in order to be lost to the circulatory system.

From the results, slaughter treatment had an effect on both rates of blood loss and the length of the interval between the initiation of exsanguination and the cessation of heart function. The period of heart function was significantly shorter for the complete gash cut treatment group indicating that the greater rate of blood loss also associated with the complete gash cut method caused cardiac arrest to occur earlier than in the deer from the incomplete gash cut group. The mean interval to cessation of heart function for the deer from the complete gash cut treatment group (104.5 seconds) was consistent with the mean interval of 100.8 seconds recorded for 68 fallow deer which were stunned electrically and exsanguinated by complete gash cut in other trials. The mean interval to heart cessation for those deer whose necks were not completely severed was 131.5 seconds.

In much of the literature, ecchymosis has been said to be associated with excessive pre-slaughter stress, as evident in the technical publications cited in the literature review. Ultimate pH is said to be a measure of stress or excessive exercise prior to slaughter, and increases in pH above about 5.8 are associated with an overall decrease in meat quality (MRDC, 1994). From the results of the current experiment, the ultimate pH of all the carcasses would have been considered high, and in conjunction with the high incidence of bruising in the carcasses, reflected the excessive exercise observed in the bucks prior to slaughter. The severity of the ecchymosis exhibited in this trial however, was no worse than that seen in other trials comprising similar slaughter treatments, but using deer in which excessive physical activity prior to slaughter was not observed. This would suggest that excessive physical exercise, or physical stress, prior to slaughter does not in itself pre-dispose bucks to any greater severity of ecchymosis than might otherwise be exhibited. Clearly, the proposed association between excessive pre-slaughter stress, if measured by pH, bruising or behavioral observations, and ecchymosis incidence is questionable.

The measurement of circulating cortisol concentrations is often said to indicate pre-slaughter stress also, as levels of circulating cortisol are known to increase as a result of activation of the hypothalamic-pituitary-corticoadrenal (HPA) axis (Grogan, 1998). The mean, minimum, and maximum cortisol concentrations recorded from the current experiment were no higher than those recorded from other trials in which deer did not exhibit the same aggressive pre-slaughter behaviour. This shows that aggressive physical behavior, such as that observed prior to slaughter, and physical injury as indicated by bruising, are not necessarily associated with increased pre-slaughter stress, as indicated by cortisol secretion, in bucks slaughtered in late summer at the onset of the breeding season. This result supports those of Grogan (1998), who found that in castrates administered testosterone exogenously to simulate levels common in bucks during the breeding season, increases in cortisol secretion as a result of yarding, handling and blood collection procedures appeared to be suppressed, in comparison with castrates not administered testosterone. Consistent with Grogan's work (1998), the levels of circulating testosterone in the bucks slaughtered in the current experiment, were higher than in any bucks slaughtered at other times of the year, as reported elsewhere in this study, and they reflected the onset of the breeding season, at which time testosterone levels in bucks have been previously shown to be elevated (Mulley, 1989).

Considering these results, it appears possible that associated with the onset of the breeding season, bucks may be less physiologically responsive to events that would at other times of the year, or in other sex types, be considered emotionally stressful. This was perhaps reflected in the low severity of ecchymosis exhibited, considering the nature of the slaughter treatments used, the range of cortisol concentrations recorded, and the physical trauma inflicted during the pre-slaughter period. The relationship between sex type and the incidence of ecchymosis, and seasonal changes associated with sex type and their relationship to cortisol, testosterone and progesterone secretion, are explored further in a later section.

6.3 Slaughter methods and rates of blood loss

As discussed in the case studies report, a number of different combinations of stunning and exsanguination methods were observed to be used in the various abattoirs slaughtering deer. These included; electrical stunning followed by the gash cut method of exsanguination (EG), electrical stunning followed by the thoracic stick method of exsanguination (ET), captive bolt stunning followed by the gash cut method of exsanguination (CG), and captive bolt stunning followed by the thoracic stick method of exsanguination (CT).

At the type B abattoirs studied, where the gash cut method of exsanguination was used, the slaughterman was always located on left hand side of the deer on its exit from the v-restraining conveyer. Thus for a right handed slaughterman the left hand was used to stretch the head of the deer back and the right hand was used to execute the gash cut drawing the knife upwards from the bottom of side of the neck to the top with the blade pointing down. In one type D1 abattoir studied, where deer were captive bolt stunned or shot with a 22 calibre rifle, the slaughterman was located on the right hand side of the deer as it fell out on to the slaughter table. The slaughterman being a right hander had to stand in front of the deer, bend to be in a position to exsanguinate the deer, and instead of drawing the knife with the blade pointing downward from the bottom side of the neck to the top, he had to hold the knife with the blade pointing upward and cut from the top of the neck to the bottom. In many instances the first attempt at exsanguination was unsuccessful and a second attempt had to be made. Although the rate of blood loss was not measured it was observed that when incomplete severance did occur only one stream of blood appeared from the wound as opposed to two when both sides of the neck were severed. This added another variation to the aforementioned combinations of stunning and exsanguination methods. Electrical stunning was the method observed most often to be used in the ritual Muslim slaughter of fallow deer and the gash cut method of exsanguination was always used. At the D1 abattoir mentioned above the use of captive bolt or a firearm was unusual so in the current study incomplete severance of the neck was considered in conjunction with electrical stunning rather than the captive bolt stunning.

A number of the trials reported in this study investigated the incidence of ecchymosis associated with these various stunning and exsanguination methods, and as part of those studies data was collected to determine the rates of blood loss associated with each. No previous work had determined the rates of blood loss induced by these different slaughter methods in deer. However, blood pressure changes and rates of blood loss associated with the thoracic stick and gash cut methods of exsanguination had been investigated in cattle and sheep.

Anil *et. al.* (1995) compared the gash cut and thoracic stick methods of exsanguination in electrically stunned calves and found that when carotid occlusion occurred as a result of the gash cut, mean arterial blood pressure could be sustained for significantly longer than the 8 seconds observed in thoracic stuck calves. Consistent with this, Gregory *et. al.* (1988) reported that the thoracic stick method of exsanguination resulted in a greater rate of blood loss than bilateral severance of the jugular veins and carotid arteries in the neck.

Blackmore and Newhook (1976) measured rates of blood loss in sheep exsanguinated by 4 different methods, including the thoracic stick and the gash cut methods. In contrast to the results of Gregory *et. al.* (1988) in cattle, Blackmore and Newhook (1976) found a greater rate of blood loss to be associated with the gash cut rather than the thoracic stick method. However, this result was determined with sheep stunned by captive bolt only. Blackmore and Newhook (1976) also compared electrical and captive bolt stunning, but only between groups of animals using two similar methods of exsanguination, one being the gash cut method and the other involving the bilateral severance of the carotid and jugular vessels of the neck, but without severing the oesophagus. The results showed a greater rate of blood loss to be associated with electrical stunning than captive bolt.

This chapter explores the rate of blood loss associated with five combinations of stunning and exsanguination methods including:

- electrical stunning followed by the gash cut method of exsanguination (EG);
- electrical stunning followed by the thoracic stick method of exsanguination (ET);
- captive bolt stunning followed by the gash cut method of exsanguination (CG);
- captive bolt stunning followed by the thoracic stick method of exsanguination (CT); and
- captive bolt stunning followed by the incomplete severance of the extended neck (CG1).

Materials and Methods

Animals

Data was collected from four separate trials. Two of the trials comprised 48 fallow does slaughtered at the UWSH abattoir, one trial involving 72 deer comprised of equal numbers of castrates, does, and bucks slaughtered at a type D2 abattoir, and one trial also conducted at the UWSH abattoir comprised of 12 bucks only.

Treatments

The first three aforementioned trials compared four combinations of stunning and exsanguination methods including EG (Electrical stun, gash cut), ET (Electrical stun, thoracic stick), CG (Captive bolt, gash cut), and CT (Captive bolt, thoracic stick) mentioned in the introduction. Electrical stunning was at 400 volts for 3 seconds in the first two trials and 250 volts for 2 seconds in the trial conducted at the D2 abattoir. The bucks slaughtered in the fourth trial were all electrically stunned using 400 volts for 1 second, following which, half were exsanguinated by the gash cut method, and the other half by severing blood vessels on the right hand side of the extended neck only (EG1). The interval between stunning and exsanguination was similar for all trials and treatment groups and ranged from approximately 8 to 15 seconds.

Measurement of Rate of Blood Loss

Blood was collected into a large plastic bag for 10 seconds from the time exsanguination was initiated. The bag and blood were then weighed. The deer which were exsanguinated using the gash cut method, remained in lateral recumbancy, but had their hind legs held approximately 80 cm off the floor for the collection period. The thoracic stuck deer were exsanguinated after hoisting onto the dressing out rail.

Carcasses were inspected before skinning and during evisceration to establish if there was excessive blood retention in either the hide or the pleural cavity. Retention of blood in the pleural cavity following exsanguination by thoracic stick had been observed in previous studies on sheep (Blackmore and Newhook, 1976). They were also inspected for ecchymosis, but these results are discussed in the relevant experimental section.

Data Analysis

The effects of exsanguination method and stunning were fitted to the blood loss data using residual maximum likelihood (Patterson and Thompson, 1971). Each slaughter trial was fitted as part of the random model. The Wald statistic was used to assess significance of fitted effects.

Results

Figure 6.1: Weight of blood collected during the 10 seconds subsequent to the initiation of exsanguination in fallow deer slaughtered by five different combinations of stunning and exsanguination methods.

The overall effect of exsanguination method was highly significant ($p < 0.001$) with the thoracic stick method of exsanguination resulting in the greatest weight of blood being collected in the 10 second collection period. The overall effect of stunning method was not significant although there was a significant ($p < 0.05$) stunning method by exsanguination method interaction

Listed from the highest to the lowest predicted mean weight of blood collected the treatment groups were in the order of ET, CT, CG, EG and EG1 (Table 6.3).

Table 6.3: Predicted mean weights (gms) of blood collected from five stunning and exsanguination method combinations (Calculated using residual maximum likelihood).

	Captive bolt	Electrical stun
Thoracic stick	1072.7	1458.7
Gash cut	684.5	463.7
Gash cut (1 side only)	-	228.5

Discussion

The results for rate of blood loss associated with the thoracic stick and gash cut methods of bleeding, following electrical stunning in deer, were consistent with those from work on calves reported by Gregory *et. al.* (1988) and Anil (1995), whereby the thoracic stick method caused a greater rate of blood loss than the gash cut method. Following captive bolt stunning the same pattern occurred, although the difference between the mean predicted blood loss weights for each of the exsanguination methods was less for the captive bolt stunned group (338 gm) than the electrically stunned group (995 gm). The incomplete severance of the neck resulted in the least amount of blood collected which was half that of the complete severance method.

The rate of blood loss was lower when the thoracic stick method of exsanguination followed captive bolt stunning, compared with when the thoracic stick method of exsanguination followed electrical stunning (386 gm) and this may have been due to a shorter tonic phase occurring with captive bolt stunning. If a shorter tonic phase was associated with captive bolt stunning then it is likely that blood circulation to the musculature would have resumed at least 5 seconds prior to the initiation of exsanguination. It could therefore be predicted that less blood would have been in the blood vessels of the thoracic cavity of the deer stunned by captive bolt than there would have been in the electrically stunned deer. Given that the thoracic cavity was the site of incision and consequent blood loss, this would have resulted in the significantly different rates of blood loss between the two methods of stunning.

In a previous trial investigating the effect of electrical and captive bolt stunning methods combined with either a long (25-30 seconds) or short (6 seconds) interval between stunning and exsanguination using the thoracic stick method it was found that in deer where the incidence of ecchymosis was lowest in the lungs it was highest in the skeletal muscles, and the inverse applied, where, if ecchymosis was highest in the lungs, it was lowest in the skeletal muscles. Exsanguination after the long interval was common to the slaughter treatment groups associated with both the best and worst incidence of ecchymosis in the lungs, but the stunning methods were different. Captive bolt stunning was associated with the least incidence of ecchymosis in the lungs and electrical stunning the worst. Briefly, it was postulated that electrical stunning caused a concentration of blood volume in the viscera, particularly the lungs, as a result of prolonged tonic phase muscular contractions (10 seconds) common to this stunning method. While the blood volume was concentrated in the viscera, it was not available in the musculature to leak out of ruptured blood vessels. The inverse was suggested to have applied with captive bolt stunning where the tonic phase may have been of a much shorter duration (< 5 seconds), as is common with this method, and therefore did not result in as great a volume of blood rerouting to the viscera. With the delayed interval to exsanguination the blood that had rerouted to the viscera would have had ample time to return to the musculature and cause ecchymosis therein. The results of the current study indicate that blood volume was more concentrated in the thoracic cavity of electrically stunned deer than captive bolt stunned deer and this further substantiated the aforementioned proposition regarding blood distribution related to stunning, and its effect on the distribution of ecchymosis between the visceral organs and skeletal muscles.

In a previous trial conducted at a type B abattoir the thoracic stick method of exsanguination was observed to reduce significantly the incidence of ecchymosis in the skeletal muscle of electrically stunned fallow deer in comparison to the gash cut method. In this trial exsanguination was initiated within five seconds of stunning and hence it occurred while the deer were still in the tonic phase. It was postulated that due to the site of incision with the thoracic stick method, being adjacent to the region of greatest blood volume concentration, resulted in blood being lost before it could return to the musculature and cause ecchymosis, whereas the gash cut method required the blood to return to circulation to reach the region of the incision and escape. The results of the current study substantiate this proposition regarding blood distribution, associated blood loss related to the site of incision, and its influence on the incidence of ecchymosis.

In deer exsanguinated by the gash cut method of exsanguination in the current study, captive bolt stunning was associated with a greater rate of blood loss than electrical stunning (221 gm). This result was the inverse to that seen with the thoracic stick method. While in the thoracic stuck deer, it was proposed that electrical stunning caused a greater rate of blood loss by contracting musculature and thereby rerouting blood to the site of the incision, in the case of the gash cut, the contraction of skeletal muscles and rerouting of blood to the thoracic cavity may have acted to the detriment of blood loss. The tonic contraction of muscles in the neck at the time that the gash cut incision was made perhaps helped to occlude the severed common carotid arteries and jugular veins. In addition to this, for blood to be lost from the incision of the neck, circulation would have to resume to move blood from the thoracic cavity region to the peripheral vascular bed. With captive bolt stunning the duration of the tonic phase was greatly reduced, with a consequent reduction of the effects of vaso-constriction of muscle blood vessels on blood distribution. Hence the detrimental nature of these factors on blood loss when using the gash cut method was less pronounced.

The results from the current work in deer were in contrast to those of Blackmore and Newhook (1978) who measured rates of blood loss from captive bolt stunned sheep exsanguinated by either the gash cut or thoracic stick methods, and found the greater rate of blood loss to be associated with the gash cut. Blackmore and Newhook (1978) also compared rates of blood loss between sheep exsanguinated using the gash cut method after either captive bolt stunning or electrical stunning. Again, their results were not consistent with the results in this study, and showed the rate of blood loss to be greater for electrically stunned sheep than captive bolt stunned sheep. However similar data were obtained for the exsanguination of cattle (Gregory *et. al.*, 1988) as for the deer in this study.

The difference in results for the cattle and deer, compared to the sheep, may have been due to either the method of blood collection used in each trial, or alternatively may have been related to observations by Gregory *et. al.* (1988) that occlusion of the common carotid artery was more likely to occur in calves than sheep. Regarding the latter proposition, in the case of calves, occlusion of the common carotid artery may have led to a lower rate of blood loss when using the gash cut method of exsanguination, than would occur in sheep said to be less susceptible to common carotid artery occlusion. For the former proposition concerning blood collection methods, Blackmore and Newhook (1978) noted the retention of blood in the pleural cavity of sheep exsanguinated by the thoracic stick method. This may have occurred as a result of the sheep remaining in lateral recumbency for the initial period of exsanguination, whereas the deer exsanguinated by the thoracic stick method were hoisted on to the dressing rail prior to exsanguination in the present study and this is also likely in the case of cattle. It is also possible that more blood was retained in the wool of the sheep than would remain in the hide of cattle or deer. In the present study, excessive blood retention in the pleural cavity, or on the hide of the deer was not evident from the inspection of the animals prior to skinning and during evisceration.

At a type D1 abattoir it was observed that due to the location of the slaughterman relative to the deer awaiting exsanguination, often more than one attempt needed to be made to sever all the blood vessels of the extended neck. In the position that the slaughterman was forced to stand he appeared to have difficulty drawing the knife entirely from one side of the neck to the other to sever the common carotid arteries and jugular veins on both sides of the neck. In the current study, the severance of the blood vessels on the left hand side of the extended neck only, led to a blood loss weight of approximately half that caused by complete severance of the blood vessels on both sides of the neck. The experiment was designed to emulate what had been observed to occur in the commercial situation, and should the incidence of ecchymosis be associated with a lesser rate of blood loss, this would help to explain the occurrence of ecchymosis at some abattoirs. However, differences between the groups in terms of expression of ecchymosis were not significant, and it is concluded that the effect of incomplete severance of all of the major blood vessels at the time of exsanguination is of little consequence, apart from perhaps being regarded as poor slaughter technique.

7. Stunning and exsanguination combinations

7.1 Introduction

At the commencement of this study (1996) there was only one type B export abattoir available to slaughter fallow deer from Queensland, NSW, Victoria, and South Australia for export from Australia, and that abattoir slaughtered all deer according to Muslim custom, which involved head only electrical stunning followed by the gash cut method of exsanguination. A number of trials were conducted at the type B abattoir referred to and it was found that if the thoracic stick method of exsanguination was used instead of the gash cut method in the slaughter process, while all other factors remained the same, the incidence of ecchymosis was reduced considerably. These results supported claims made by venison processors who had previously slaughtered fallow deer at other type B abattoirs that incorporated the thoracic stick method or permutations of it into the slaughter process, but which had since ceased slaughtering deer. Unfortunately, the Muslim slaughterman at the remaining type B abattoir would not allow the thoracic stick method or any permutations of it, to be incorporated into the slaughter process. Consequently, the only avenue related to the slaughter system for the potential reduction of ecchymosis in fallow deer was the manipulation of the electrical stunning method. Different voltages and variations to stun current duration were tested with no treatment effect found between voltage and ecchymosis incidence. The length of the stun current was shown to have an effect on ecchymosis incidence in one trial involving a small group of deer of the same sex and similar age, weight, and known pre-slaughter history. However, this result was not repeated in less homologous groups of animals.

Towards the end of the current study (1998) a number of new abattoirs, some said to be deer specialist abattoirs (Type D2) and others built initially to slaughter ratites (Type D1) commenced slaughtering deer. Initially, most of these abattoirs slaughtered deer according to the requirements of their Muslim slaughterman, although adherence to convention by these slaughtermen was observed to vary considerably between establishments. In addition to permutations of the thoracic stick method of exsanguination being incorporated into these slaughter systems, other methods of stunning were observed including percussion stunning and shooting with a .22 calibre firearm. These abattoirs were also accredited to slaughter deer for export to non-Muslim markets in Europe and America, and as the Muslim market demand for venison decreased the propensity for processors to slaughter all stock to Muslim specifications diminished, creating the opportunity for the implementation of alternative stunning and exsanguination methods.

Alternative methods of stunning, some of which had been shown to reduce the incidence of ecchymosis in other species of livestock were discussed previously. They included; head to body electrical stunning, high frequency electrical stunning, carbon dioxide stunning, percussion stunning, penetrative captive bolt stunning, and shooting with a .22 calibre firearm. Barriers to the implementation of these alternative methods of stunning in the venison processing sector included broadly; non-conformance to Muslim slaughter requirements, establishment cost, operating cost, ability to be integrated into existing slaughter systems, safety, and limited knowledge of their application on deer and/or other species. Of these rationale, non-conformance to Muslim slaughter requirements was the one factor that limited the potential implementation of all the alternatives.

Without the need to adhere to Muslim slaughter requirements all of the alternative stunning methods mentioned above were considered culturally feasible by the end of the current study (1998). However, their implementation was still subject to there being a potential economic return on the capital cost of required infrastructural changes and ongoing operating costs. In the D1 and D2 type abattoirs, the restraint devices installed precluded the use of a head to back electrical stunner, although the method still remained an option for type B abattoirs with the v-restraining conveyers. From previous studies in sheep (Petersen *et. al.*, 1986) it was determined that while head to back stunning almost eliminated the incidence of ecchymosis, it increased the incidence of the other haemorraghic syndrome ‘speckle’, and some preliminary research in deer would be necessary. Research would also be required to determine the efficacy of both high frequency electrical stunning and carbon dioxide stunning as options for use in deer slaughter systems prior to considering implementation and the later of these methods would also require substantial capital investment. Shooting with a .22 calibre firearm was not feasible on the grounds of compromising safety of abattoir workers. Ultimately, the most culturally and economically feasible alternatives for type D1 and D2 abattoirs were the penetrative captive bolt or percussion stunning methods. Percussion stunning was observed at one type D1 abattoir slaughtering fallow deer. However, time constraints to the current study precluded this method being investigated further.

As a consequence of the Muslim market for Australian venison diminishing, all four possible combinations of stunning and exsanguination methods comprising head only electrical and captive bolt stunning, and thoracic stick and gash cut methods of exsanguination were able to be considered for the slaughter of deer in the D1 and D2 type abattoirs. In addition to this, at the time of writing the type B abattoir which had previously only slaughtered deer for the Muslim market was obtaining accreditation for export to non-Muslim markets, and another type B abattoir that had not slaughtered deer throughout the duration of the project but was already accredited for export to non-Muslim markets recommenced operation. This broadened even further the types of slaughter systems available for fallow deer. While the same combinations of stunning and exsanguination methods could be implemented at both type B and type D abattoirs they were still considerably different with respect to the method of restraint used and the minimum interval between stunning and exsanguination that could be achieved. At the type B abattoirs the interval was consistently less than 5 seconds, while at the type D abattoirs it was seldom less than 15 seconds and often as long as 30 seconds.

Research in lambs showed captive bolt stunning to be associated with a lower incidence of ecchymosis than head only and high frequency electrical stunning when followed by gash cut exsanguination (Spencer, 1979; Kirton *et. al.*, 1981b). In an experiment comparing head only electrical stunning with captive bolt stunning prior to gash cut exsanguination, Grogan (1998) also reported a significantly higher incidence of ecchymosis in the carcasses of the electrically stunned fallow deer. The work of Spencer (1979), Kirton *et. al.* (1981b), and Grogan (1998) however, had limited relevance to the potential for captive bolt stunning to reduce ecchymosis incidence in type D abattoirs due to a number of complicating factors. Firstly, the work of the aforementioned researchers was conducted at type B abattoirs where the interval between stunning and exsanguination was considerably less than that which could be achieved at type D abattoirs. Secondly, all the experiments involved the use of the gash cut method of exsanguination which in most type D abattoirs had been replaced or combined with the use of the thoracic stick method. Finally, Grogan (1998) reported 70 volts being used to stun the deer in his trial which from the results of the current study, would not have induced the typical tonic phase reaction normally observed in electrically stunned fallow deer.

With the eventual dominance of type D abattoirs in the Australian venison processing sector, considering the effect of the interval between stunning and exsanguination became a necessary extension of the aforementioned work in lambs and deer, which was conducted in type B abattoirs only, with intervals consistently less than 5 seconds. Burson *et. al.* (1983) compared the incidence of ecchymosis in pigs exsanguinated after captive bolt stunning within 18 seconds and after 144 seconds and found the incidence to be higher in the carcasses of the pigs exsanguinated after 144 seconds. The same authors then extended their work to consider pigs slaughtered by captive bolt and electrical stunning under both delayed and short interval exsanguination regimes. Captive bolt/delayed exsanguination (91.3 sec.) was associated with a higher incidence of ecchymosis, but there was no significant difference between the incidence of ecchymosis associated with either captive bolt/short exsanguination (8.4 sec.), electrical stun/short exsanguination (9.0 sec.) or, electrical stun/delayed exsanguination (100 sec.). The work of Burson *et. al.* (1983) on pigs was particularly relevant to current (1998) venison processing practices in Australia, as all pigs in that study were exsanguinated by the thoracic stick method of exsanguination. Kirton *et. al.* (1978) investigated the interval between stunning and exsanguination in sheep. However, again it was more relevant to type B abattoirs with the intervals tested being just before, within 5 seconds, and 8 seconds after stunning. The method of exsanguination used was the gash cut method. The incidence of ecchymosis was greater in the sheep exsanguinated at the longest interval. However, as Kirton *et. al.* (1978) reported, the incidence of ecchymosis was less than that seen in some normal slaughter lines exsanguinated at the shorter interval.

This section reports experiments which were conducted to investigate the effect of 4 stunning and exsanguination combinations comprising, captive bolt and electrical stunning and thoracic stick and gash cut exsanguination, on ecchymosis incidence in two groups of does. The deer were slaughtered at the UWSH abattoir where the interval between stunning and exsanguination was maintained at approximately 10 seconds, which was the also the shortest interval considered possible at type D abattoirs.

Furthermore, another two trials which investigated the effect of two different intervals between stunning and exsanguination on ecchymosis incidence in does are described. The deer were stunned either electrically or by captive bolt, and all were exsanguinated using the thoracic stick method.

In order to maintain a continuous supply of deer for slaughter throughout the year, three sex types are commercially available at different times. Bucks are generally slaughtered from late spring through to the end of summer, after which the slaughter of bucks becomes undesirable due to their aggressive rutting behaviour. Does and castrates can be slaughtered year round but are normally kept for slaughter during the rut, from autumn through to late winter. Does which fail to conceive can be determined and sold for slaughter appropriately during this period.

In experiments which compared the carcasses of head-only electrically stunned fallow deer bled by either gash cut or thoracic stick, the gash cut method was associated with a significantly higher incidence of ecchymosis. One of the experiments involved non pregnant does slaughtered in spring and the other involved bucks slaughtered in late summer. While the effect of slaughter treatment on the incidence of ecchymosis in both trials was the same, the severity of the ecchymosis exhibited in the trial using does was significantly greater than in the trial using bucks. While there were numerous other potentially confounding factors between the two trials, it was possible that the does had a greater predisposition to ecchymosis than the bucks. In another experiment, which compared incomplete with complete severance of the neck using a gash cut, twelve fallow bucks were slaughtered in late summer (February) when they were beginning to show aggressive behaviour associated with the rut. In that trial there was no significant treatment effect observed on the incidence of ecchymosis, with there being considerably less ecchymosis than was seen in trials using slaughter methods considered to be more favourable to reducing ecchymosis. This was surprising considering all the bucks showed post-mortem signs of extensive pre-slaughter stress, including high pH and bruising. The bucks had not been subjected to any increased form of pre-slaughter habituation to handling either. In a further experiment, which investigated the effect of restraint on the expression of ecchymosis and which inadvertently included 2 pregnant does, an entire buck and 10 castrates, there appeared to be an association between sex type and ecchymosis. From the data obtained from these studies it was apparent that physiological changes in fallow deer associated with sex type and time of year may be important considerations in attempts to minimise the prevalence of ecchymosis.

In work on ecchymosis in other species, results between seemingly similar experiments and/or slaughter systems were often completely inconsistent with each other. Some authors were led to describe this phenomena as an unexplained ‘day effect’ (Kirton and Frazerhurst, 1983) or when seen in the commercial situation, a ‘mob (farm) effect’ (Pearson *et. al.*, 1977). In few of these experiments was sex type considered as a potential pre-disposing factor to ecchymosis. In sheep, most of the work on ecchymosis was conducted using groups of lambs comprising both ewes and wethers (castrates) but results pertaining to the two sex types were not differentiated. No work has been done to compare ecchymosis between entire male lambs and castrates, perhaps because when the work in lambs was carried out in New Zealand in the 1980’s male lambs were generally always castrated. In pigs, one study considered sex type and ecchymosis, comparing barrows and gilt’s (Burson *et. al.*, 1983), but no effect was shown between these two sex types and ecchymosis.

A further experiment in this section sought to clarify the effect of 4 stunning and exsanguination combinations comprising captive bolt and electrical stunning and thoracic stick and gash cut exsanguination, on ecchymosis at a type D abattoir where the interval between stunning and exsanguination was approximately 15 seconds. The effect of sex type on the incidence of ecchymosis was also investigated.

In a number of previous experiments blood plasma constituents including cortisol, testosterone and progesterone were measured. Mean cortisol concentration levels for two groups of castrates slaughtered at the UWSH abattoir were 91 *ng/mL* and 65 *ng/mL* the day before slaughter, and 106 *ng/mL* and 96 *ng/mL* at slaughter. For a group of bucks also slaughtered at the UWSH abattoir the mean cortisol level the day before slaughter was 73 *ng/mL* and at slaughter 74 *ng/mL*. In another trial, conducted at the UWSH abattoir the mean cortisol level for a group of bucks at slaughter was 84 *ng/mL* and from blood samples collected from fallow deer of unknown sex type or pre-slaughter history at a type D1 abattoir the mean level of cortisol at slaughter was 81 *ng/mL*. Within the range of circulating testosterone and cortisol levels which occurred in the deer slaughtered at the UWSH abattoir no relationship was observed between either of these hormones and the incidence of ecchymosis, and no relationship was observed between cortisol and testosterone levels. Extending previous studies blood plasma samples were also collected from deer slaughtered in the trials reported in this chapter and analysed for circulating cortisol, testosterone and progesterone. As an indicator of pre-slaughter stress, ultimate carcass pH was also determined in this trial. The experiments also contributed data to the determination of rates of blood loss associated with slaughter methods.

7.2 The effect of stunning and exsanguination method on ecchymosis

By early 1998, the dominance of the Muslim market for Australian venison had diminished and a number of alternatives to the existing type B abattoir, became available to slaughter deer. This meant that four combinations of stunning and exsanguination methods comprising head only electrical and captive bolt stunning, and thoracic stick and gash cut methods of exsanguination, were able to be considered for the slaughter of deer.

Previous experiments showed the thoracic stick method of exsanguination to reduce the incidence of ecchymosis compared with the gash cut method when incorporated into the type B abattoir slaughter systems where the interval between stunning and exsanguination was less than 5 seconds. In contrast, the shortest interval possible at the new type D abattoirs was generally around 15 seconds. In addition to this, the aforementioned experiments involved only head only electrical stunning as that was the favoured method of stunning used at type B abattoirs because it incurred minimal operating costs and enabled the stunner and slaughterman to keep up with the speed at which the remainder of the processing chain could operate. In the new type D abattoirs where the rate of slaughter was considerably slower than at type B abattoirs, captive bolt stunning appeared to be the preferred method of stunning. From discussions with the management of two type D abattoirs it was revealed that when electrical stunning had been attempted, it was unsuccessful in inducing tonic spasms in deer and reports of deer running around the slaughter floor were forthcoming. Although this appeared to be due to lack of familiarity with the correct procedure on the part of the stunner operator, it had created a strong aversion to use of the technique by the staff involved.

The current experiments investigated the effect of four combinations of stunning and exsanguination methods on the incidence of ecchymosis in fallow does.

Circulating cortisol and testosterone concentrations from plasma samples collected the day before, and at slaughter, from bucks and castrates slaughtered at the UWSH abattoir were determined. In none of these trials were either of these hormones observed to affect the incidence of ecchymosis. In the current experiments cortisol and progesterone levels were determined for does also slaughtered at the UWSH abattoir.

Materials and Methods

Animals and Pre-slaughter Treatment

Fallow does of mixed ages were slaughtered in two trials at the UWSH abattoir in Spring (October). The does originated from the same farm and had been held at UWSH farm for two months at the time of the first slaughter. The trials were conducted a week apart. The does had been maintained on a Kikuyu based pasture with no supplementation. For each trial the deer were yarded at noon the day before slaughter and weighed. The mean live weight of the does was 45.2kg (SEM $\pm$ 0.7) for those from the first trial (n= 23) (trial A) and 45.4kg (SEM $\pm$ 0.7) for those from the second trial (n= 25) (trial B). Blood was collected via jugular venepuncture from the does used in trial A the day before slaughter. The deer remained overnight in the deer unit handling shed and were moved to the abattoir the following morning, a distance of approximately 180 metres. The deer had no access to food or water during the 19 hours prior to slaughter.

Allocation to Treatment Groups

The does were allocated to treatment groups in a 2 x 2 factorial design accounting for 2 stunning and 2 exsanguination methods. The slaughter treatment groups comprised:
1) Electrical stunning and gash cut exsanguination (ESGC);
2) Electrical stunning and thoracic stick exsanguination (ESTS);
3) Penetrative captive bolt stunning and gash cut exsanguination (CBGC); and
4) Penetrative captive bolt stunning and thoracic stick exsanguination (CBTS).

Stunning and Exsanguination Techniques

Consistent with the experiments investigating exsanguination methods at the type B abattoir, electrical stunning was carried out using 400 volts for a duration of 3 seconds. Captive bolt stunning was as previously described and the deer were bled by either the gash cut or thoracic stick method of exsanguination.

At the start of trial A attempts were made to exsanguinate the first six deer, from both the gash cut and thoracic stick treatment groups, after hoisting by a hind leg. The gash cutting of the hoisted deer was found to be extremely difficult with the deer in this position and complete severance of both common carotid arteries and jugular veins in some of those deer could not be completed with certainty. As a result, the remaining deer from the gash cut treatment group were exsanguinated prior to hoisting. In trial B the deer in the gash cut treatment group were all exsanguinated while recumbent, and the thoracic stick treatment group after hoisting. For all treatment groups in both trials the duration between stunning and exsanguination was maintained at approximately 10 seconds.

Measurements

The rate of blood loss was measured by collecting blood in plastic garbage bags for 10 seconds following the commencement of exsanguination. Blood samples were also collected via jugular venepuncture the day prior to slaughter and at exsanguination from the does used in trial A and circulating cortisol and progesterone concentrations were measured. The uterus of each of the does was inspected during evisceration to determine whether the does were pregnant or not. Peak stun current was recorded and carcass weight was measured just prior to chilling. Ecchymosis was graded using the boning room method previously described.

Statistical Analysis

Carcasses were classified as ‘affected’ or ‘not affected’ by ecchymosis on the basis of the total loin, round and rump ecchymosis scores, and data was analysed using Chi-squared test (Minitab 9, 1995).

Results

Carcass Weights

The mean HCW of the does slaughtered in trial A and trial B were 24.4kg (SEM ± 0.6), and 24.5kg (SEM ± 0.5) respectively.

Peak Stun Currents

The mean peak stun current recorded in trial A was 2.48 amps (SEM ± 0.15) and in trial B it was 2.83 amps (SEM ± 0.21).

Pregnancy Status

1 of the does from trial A was diagnosed not pregnant by visual examination of the uterus and the circulating progesterone concentration which was 0.17 *ng/mL* as opposed to the mean circulating progesterone concentration for the pregnant does of 6.61 *ng/mL* (SEM ± 0.39). 3 of the does from trial B were diagnosed not pregnant by examination of the uterus. All of the pregnant does exhibited ecchymosis but the number of animals was too small to indicate whether pregnancy status affected ecchymosis incidence or not.

Circulating Cortisol Concentrations

The mean circulating cortisol concentrations measured from the samples taken the day prior to slaughter, and at slaughter were 73 *ng/mL* (SEM ± 5.3) and 93 *ng/mL* (SEM ± 4.2) respectively. When assay data for individual animals was ranked according to cortisol levels taken the day before slaughter, there was no apparent relationship to cortisol levels taken at slaughter. When the individual assay data was ranked according to progesterone levels there was no relationship between progesterone and cortisol levels either. There were no relationships to be observed between ecchymosis incidence and individual cortisol concentrations within the range that occurred before or at slaughter.

Table 7.1: Trial A ecchymosis scores and blood loss data for does slaughtered by 4 combinations of stunning and exsanguination methods.

.	Captive bolt					Electrical stun				
	Loin	Round	Rump	Total score	Blood loss (gm)	Loin	Round	Rump	Total score	Blood loss (gm)
Gash cut	1 1	3 2	3 1	11	647.1	3 3	4 4	3 4	21	794.1
	0 0	2 3	1 1	7	776.6	2 3	4 4	4 4	21	472.1
	0 1	3 2	0 1	7*	719.6	0 0	1 1	0 0	2	372.1
	0 1	1 1	1 1	5	642.7	0 0	0 1	0 0	1	417.9
	0 0	1 0	0 0	1	751.9	0 0	0 0	0 0	0	448.2
	0 0	0 0	0 1	1	337.3	0 0	0 0	0 0	0	783.7
Thoracic stick	2 3	4 4	3 3	19	602.6	1 1	1 1	2 3	9	625.8
	1 2	3 4	1 1	12	813.4	1 2	1 1	1 3	9	1509.7
	0 0	1 1	0 0	2	860.6	1 1	0 1	2 1	6	1592.3
	0 0	1 1	0 0	2	1017.5	1 0	1 1	0 1	4	861.3
	0 0	1 0	0 0	1	395.8	0 1	1 0	0 0	2	1690.9
	-	-	-	-	-	0 0	0 0	0 0	0	1336.2

*not pregnant

Table 7.2: Trial B ecchymosis scores and blood loss data for does slaughtered by four combinations of stunning and exsanguination methods.

.	Captive bolt					Electrical stun				
	Loin	Round	Rump	Total score	Blood loss (gm)	Loin	Round	Rump	Total score	Blood loss (gm)
Gash cut	2 2	2 2	1 1	10	805.6	2 2	2 4	2 2	14	272.4
	0 1	2 2	1 2	8	1162.3	3 3	3 4	4 4	21	785.2
	0 0	0 1	0 1	2	983.1	1 1	2 2	2 1	9*	652.2
	0 0	0 0	1 0	1	786.5	1 0	1 0	1 0	3	472.3
	0 0	0 0	0 0	0	857.9	1 1	0 0	0 0	2	305.2
	0 0	0 0	0 0	0	675.8	0 1	0 0	1 1	3	640.3
	0 0	0 0	0 0	0	974.3	0 0	0 0	0 1	1	654.7
Thoracic stick	1 1	0 1	0 1	4	1935.7	2 2	2 3	3 4	16*	1885.8
	1 0	0 1	1 1	4	1082.2	1 2	3 4	2 2	14*	1296.7
	0 1	0 1	0 0	2	1461.6	0 0	0 1	0 1	2	2071.0
	0 0	0 0	0 0	0	1450.9	0 0	0 0	0 1	1	1790.6
	0 0	0 0	0 0	0	637.8	0 0	0 0	0 0	0	811.5
	-	-	-	-	-	0 0	0 0	0 0	0	1901.6

* not pregnant

For each of the slaughter treatment groups over half of the carcasses exhibited ecchymosis in either the loin, round or rump. There was no slaughter treatment effect observed in either trial on the incidence of ecchymosis. When data from both trials was pooled neither stunning or exsanguination method were observed to affect the incidence of ecchymosis (Table 7.1 and Table 7.2).

Discussion

The peak stun currents recorded in these trials were consistent with those recorded in other trials for the same voltage and stun current duration. As with the live weights the carcass weights of the deer from these experiments reflected little variation in size between individual animals within or between experiments.

The cortisol levels observed for the does both the day before and at slaughter in this trial were within the range observed in other trials involving bucks and castrates also slaughtered at the UWSH abattoir. The mean cortisol level in the does was greater at slaughter than the day before and this reflected the results from castrates in earlier trials, but not the bucks which had similar cortisol levels before and at slaughter. This may have indicated a sex type difference with respect to hormonal responses to consecutive handling treatments. As was also observed in bucks and castrates there was no relationship apparent between cortisol levels and ecchymosis expression in the does. In the aforementioned castrate and buck trials testosterone levels were not observed to affect cortisol levels or ecchymosis expression. In the current study there was no relationship observed between progesterone and cortisol levels, or ecchymosis expression.

In contrast to previous studies in which the thoracic stick method of exsanguination was incorporated into a type B abattoir slaughter system in place of the gash cut method, the current study showed no exsanguination method effect on the incidence of ecchymosis. Furthermore, the current study showed stunning method to have no effect on ecchymosis. This was in contrast to studies using sheep (Spencer, 1979; Kirton *et. al.*, 1981b) and deer (Grogan, 1998) whereby a higher incidence of ecchymosis was attributed to electrical stunning in comparison with captive bolt stunning, although the results of the deer study were questionable on the basis of the voltage used (70 volts). The contrast in the results between the current study and other studies may have been due to a relationship existing between stunning and exsanguination methods and the interval between stunning and exsanguination, which at the type B abattoir was less than 5 seconds, but at the UWSH abattoir in which this study was conducted, was approximately 10 seconds. This was studied in subsequent trials.

It would appear from the results that although there was no slaughter treatment effect observed on the incidence of ecchymosis, on an individual animal basis some of the does were affected more than others, perhaps suggesting that some animals may be physiologically more pre-disposed to ecchymosis than others. If this were so, small numbers of deer such as those used in the current experiments would make conclusions difficult to draw, especially where the effects of treatments were very subtle.

7.3 The effect of interval between stunning and exsanguination on ecchymosis

Previous experiments investigated the effect of four slaughter treatments on the incidence of ecchymosis in fallow does slaughtered at the UWSH abattoir. The four slaughter treatments comprised electrical and captive bolt stunning and gash cut and thoracic stick exsanguination methods. No treatment effect was shown for any of the stunning and exsanguination method combinations, nor was any treatment effect shown for either stunning or exsanguination method alone. These results were in contrast to earlier experiments which investigated the same exsanguination methods with similar numbers of deer and showed a highly significant exsanguination method effect. In addition to this, previous research in lambs had shown captive bolt stunning to be associated with a lesser incidence of ecchymosis than head only electrical stunning (Spencer, 1979; Kirton *et. al.*, 1981b), and more recent work by Grogan (1998) suggested this to be the case in fallow deer also.

One of the factors considered to be of importance in explaining the contrasting results of the previous deer trials involving slaughter method, was the length of the interval between stunning and exsanguination. The trials for which significant treatment effects were shown, including those using deer and lambs, were all conducted at type B abattoirs where the interval between stunning and exsanguination was consistently less than 5 seconds. In comparison, the trials using deer in which slaughter treatments showed no effect on ecchymosis were conducted at the UWSH abattoir where the interval was approximately 10 seconds. The interval between stunning and exsanguination was investigated previously in pigs (Burson *et. al.*, 1983) and sheep (Kirton *et. al.*, 1978). In pigs captive bolt stunning followed by exsanguination after a long interval caused a higher incidence of ecchymosis than either captive bolt stunning with a short interval to exsanguination or electrical stunning combined with either a short or long interval (Burson *et. al.*, 1983). However, the relevance of these results to the current study using deer was possibly limited due to the work in pigs involving short intervals of 18, 8.5 and 9 seconds, and long intervals of 144, 91.3 and 100 seconds in contrast to less than 5 seconds or 20 seconds observed in deer slaughter systems. In sheep the long interval was observed to cause more ecchymosis than the short interval but again the relevance of this to the current study was possibly limited because while the work in sheep considered less than 5 seconds to be a short interval it considered only 8 seconds to be long. In addition to this the work in sheep involved only electrical stunning and the gash cut method of exsanguination while the thoracic stick was used to exsanguinate all the pigs. With respect to the slaughter systems used for fallow deer in Australia, at type B abattoirs exsanguination could be initiated within 5 seconds of stunning, while at type D abattoirs the minimum possible interval was estimated to be 15 to 20 seconds and at some abattoirs intervals of greater than a minute were observed.

The trials reported in this section investigated the effect of the interval between stunning and exsanguination on the incidence of ecchymosis in fallow does, after either captive bolt or head only electrical stunning.

In previous experiments mean circulating cortisol concentrations the day before slaughter, and at slaughter were determined for does, castrates, and bucks slaughtered at the UWSH abattoir. Circulating progesterone concentrations were also recorded for the does. The present experiment extended further the data on cortisol and progesterone levels in does.

Materials and Methods

Animals and Pre-slaughter Treatment

Two groups of twenty two fallow does were slaughtered at the UWSH abattoir, one group in early spring (10th September) and the other in late spring (30th November). The deer were not weighed prior to slaughter but as an indication the mean HCW of the does in the first trial (trial C) was 25.5kg (SEM $\pm$ 0.5), and the second trial (trial D) 24.0kg (SEM $\pm$ 0.4). The does had been synchronized for mating, and at the time of slaughter were at approximately 150 (trial C) and 210 days (trial D) gestation. They had been weighed weekly for five months prior to slaughter and were therefore well habituated to handling. The does used in each trial came from two separate mobs, one of which had been maintained on a Kikuyu based pasture over sown with oats and ryegrass for winter feed, and the other which had been maintained on a Kikuyu only pasture and supplemented with a concentrate feed. For each trial the deer were yarded at noon the day before slaughter and remained overnight in the UWSH farm handling shed. They were moved to the abattoir the following morning, a distance of approximately 180 metres. The deer had no access to food or water during the 19 hours prior to slaughter.

Allocation to Treatment Groups

The does were assigned to treatment groups of a 2 x 2 factorial design accounting for 2 stunning methods and either a short or long interval between stunning and exsanguination. The slaughter treatment groups comprised:
1) Electrical stunning short stun stick time (ESS);
2) Electrical stunning long stun stick time (ESL);
3) Penetrative captive bolt stunning short stun stick time (CBS); and
4) Penetrative captive bolt stunning long stun stick time (CBL).

Stunning and Exsanguination Techniques

In one of the type D abattoirs which commenced slaughtering deer in 1998 the electrical stunner that was installed was the current-controlled type, whereby the desired current was set prior to stunning rather than the voltage. In previous work on the electrical stunning of fallow deer the same system was used and it was set at 1.0 or 1.3 amps. (Cook *et. al.*, 1994a and 1994b). For this reason, the electrical stunning in the current experiments was carried out using 250 volts for a duration of 2 seconds, which in previous trials was shown to correspond to a current of approximately 1.3 amps. Captive bolt stunning was as previously described in. The deer were all exsanguinated by the thoracic stick method. The deer from the delayed interval treatment group were exsanguinated while recumbent after being removed from the restrainer. In order to exsanguinate the deer from the short interval treatment group within 6 seconds of stunning they were exsanguinated whilst in the crush, then pulled from the crush immediately and hoisted on to the dressing out rail.

Measurements

Blood was collected from the does in trial C at exsanguination and cortisol and progesterone were measured. The uterus of each doe was examined during evisceration to determine whether the doe was pregnant or not. Ecchymosis was graded using the boning room method previously described.

Statistical Analysis

Using the total ecchymosis scores for the loins, rounds and rumps data were analysed using ANOVA (Minitab 9, 1995).

Results

Peak Stun Current
The mean peak stun current was 1.33 amps (SEM $\pm$ 0.11) in trial C, and 1.39 amps (SEM $\pm$ 0.07) in trial D.

Pregnancy Status
2 of the does from trial C, and 1 of the does from trial D were not pregnant based on the examination of the uterus of each doe. The circulating progesterone concentrations of the non pregnant does in trial C were 0.18 and 0.78 *ng/mL* compared with the mean progesterone level for the remainder of the does which was 5.3 *ng/mL* (SEM $\pm$ 0.3). When individual assay data was plotted according to ecchymosis scores there was no relationship to be observed.

Circulating Cortisol Concentrations

The mean circulating cortisol concentration determined from the samples collected at slaughter was 73.1 *ng/mL* (SEM $\pm$ 4.3). When assay data for individual animals was ranked according to cortisol levels no relationship between progesterone and cortisol levels were observed. When individual assay data was plotted according to ecchymosis scores there was no relationship.

Table 7.3: Trial C ecchymosis scores for does exsanguinated after a short or long interval from stunning by either captive bolt or electrical stunning methods.

	Captive bolt					Electrical stun				
	Loin	Round	Rump	Total score	Interval (sec.)	Loin	Round	Rump	Total score	Interval (sec.)
Long exsang. interval	4 4	4 4	3 4	23	25	1 2	3 3	3 1	13	25
	3 2	3 2	1 1	12	25	1 1	3 3	2 3	13	25
	0 2	1 2	0 0	5	25	0 1	0 0	1 0	2	25
	1 1	1 1	0 0	4	25	0 0	0 0	0 0	0	25
	0 0	1 1	0 1	3	25	0 0	0 0	0 0	0	25
	0 0	0 0	0 0	0	30*	0 0	0 0	0 0	0	20.7
Short exsang. interval	0 0	0 0	0 0	0	7.2	1 0	0 0	0 0	1	14.2
	0 0	0 0	0 0	0	4.1	0 0	0 0	0 0	0	11.9
	0 0	0 0	0 0	0	4.5	0 0	0 0	0 0	0	7.4
	0 0	0 0	0 0	0	6.7	0 0	0 0	0 0	0	15.1
	0 0	0 0	0 0	0	3.8*	0 0	0 0	0 0	0	8.3

* not pregnant, exsang. = exsanguination.

Table 7.4: Trial D ecchymosis scores for does exsanguinated after a short or long interval from stunning by either captive bolt or electrical stunning methods.

	Captive bolt					Electrical stun				
	Loin	Round	Rump	Total score	Interval (sec.)	Loin	Round	Rump	Total score	Interval (sec.)
Long exsang. interval	1 1	1 0	1 1	5	25	1 0	2 2	1 2	8	25
	1 0	0 0	0 0	1	25*	0 1	0 0	0 0	1	25
	0 0	0 0	0 0	0	25	0 1	0 0	0 0	1	25
	0 0	0 0	0 0	0	25	0 0	0 0	0 1	1	25
	0 0	0 0	0 0	0	25	0 0	0 0	0 0	0	25
Short exsang. interval	0 3	0 1	0 0	4	5.8	0 0	0 2	0 0	2	13.4
	1 0	0 0	0 0	1	4.8	1 0	0 0	0 0	1	7.9
	0 0	0 0	0 0	0	4.5	1 0	0 0	0 0	1	8.6
	0 0	0 0	0 0	0	7.5	0 0	0 0	0 0	0	4.9
	0 0	0 0	0 0	0	6.4	0 0	0 0	0 0	0	6.1
	0 0	0 0	0 0	0	6.6	0 0	0 0	0 0	0	5.0

* not pregnant, exsang. = exsanguination.

Analysing the data from each trial separately (Table 7.3 and Table 7.4), the effect of the interval between stunning and exsanguination on ecchymosis was significant ($p < 0.02$) for trial C only, with the greater amount of ecchymosis occurring in the deer from the long interval treatment group. The mean ecchymosis score for the long interval treatment group was 6.25 (SEM $\pm$ 2.13) and for the short interval treatment group it was 0.10 (SEM $\pm$ 0.10). Although not significant, the same exsanguination interval treatment effect appeared to occur in trial D and hence when the data from both trials was pooled the effect of the interval between stunning and exsanguination on ecchymosis expression became highly significant ($p < 0.008$).

Using the pooled data, although not significant ($p = 0.055$) a treatment effect with respect to each of the 4 slaughter treatment groups was observed with the captive bolt long interval treatment group having the greatest amount of ecchymosis followed by the electrical stun long interval treatment group, with the least amount occurring in the captive bolt and electrical stun short interval treatments groups. The mean total ecchymosis scores for each group were 4.82 (SEM $\pm$ 2.12), 3.55 (SEM $\pm$ 1.57), 0.46 (SEM $\pm$ 0.37), and 0.46 (SEM $\pm$ 0.21) respectively.

Discussion

The mean cortisol level at slaughter of the does in the current trial was within the range observed in previous trials. As in all other trials for which blood plasma constituents were determined, there was no relationship observed between cortisol levels and ecchymosis, or progesterone and ecchymosis.

The results of the current trial confirmed the proposition that the interval between stunning and exsanguination influenced the effect of stunning and exsanguination methods on the incidence of ecchymosis in fallow deer. This explained in part the contrasting results observed previously between trials conducted in type B abattoirs where the interval was less than 5 seconds and the UWSH abattoir where the interval was generally around 10 seconds. The results of the current trial were consistent with the previous experiments using pigs (Burson *et. al.*, 1983) despite considerable differences in the length of both the short and long intervals used. In both pigs and deer the highest incidence of ecchymosis occurred in the animals stunned by captive bolt and exsanguinated after a long interval in comparison with animals exsanguinated after the short interval, whether stunned electrically or by captive bolt.

An explanation behind this phenomena is articulated in a subsequent section, where the ecchymosis scores for the lungs of the deer used in the current experiments were presented. Briefly, the slaughter treatment effect that was observed with respect to ecchymosis incidence in the lungs of the does was in complete contrast to that which was observed with respect to ecchymosis in the skeletal muscles. It was proposed that the shorter tonic phase and longer interval between stunning and exsanguination which occurred in captive bolt long interval treatment group allowed the greatest amount of time for blood to return from the organs of the thoracic region where it had been forced by the tonic phase muscular contractions, to the skeletal muscles where it could leak out of ruptured muscle blood vessels before it was lost to the circulatory system by the initiation of exsanguination. In contrast, in deer from the short interval treatment groups the blood did not have time to reroute to the skeletal muscles before it was lost from the thoracic cavity as a result of the exsanguination procedure. If this were so, reducing ecchymosis could be contingent on ensuring that either by choice of stunning method, or timing of the initiation of exsanguination, that exsanguination occurred while the skeletal muscles of the animal were still in tonic phase contraction whereby with the thoracic stick exsanguination method the blood volume would be concentrated at the site of the incision. It was suggested in the literature that the electrical current associated with electrical stunning may itself predispose blood vessels to rupture. If this were so the most appropriate slaughter method combination for reducing ecchymosis would be captive bolt stunning with thoracic stick exsanguination initiated within 5 seconds when the tonic phase muscular contraction is still occurring. Where exsanguination was not possible within 5 seconds it may be possible that the longer tonic phase induced by electrical stunning in comparison with captive bolt stunning may be the more favourable option.

It could not be determined from the results of this study whether the incorporation of captive bolt stunning rather than electrical stunning into slaughter systems where the interval between stunning and exsanguination was less than 5 seconds and the thoracic stick method of exsanguination was used, would further reduce the incidence of ecchymosis to that which occurred when the thoracic stick method replaced the gash cut. In both the current and previous trials the incidence of ecchymosis that occurred in association with the short (<5 sec.) interval between stunning and exsanguination was so low using either the captive bolt or electrical stunning method, it would appear that considerable numbers of deer would be required to determine the effect of stunning method on ecchymosis in such slaughter systems.

7.4 Slaughter method and ecchymosis in sex effect?

Castrates, bucks and does are commercially available at different times of the year for slaughter. Bucks are generally slaughtered from late spring through to the end of summer, after which the slaughter of bucks becomes undesirable due to their aggressive rutting behaviour. Does and castrates can be slaughtered year round but are normally kept for slaughter during the rut, from autumn through to late winter. Does which fail to conceive can be slaughtered as required during this period.

In two previous trials which compared exsanguination methods incorporated into a type B abattoir slaughter system, all factors remained the same for each trial except for the date and sex type of the deer used. The same slaughter treatment effect was observed for each trial, but the severity of the ecchymosis exhibited in the trial using does was significantly greater than in the trial using bucks. In another experiment, using bucks only, considerably less ecchymosis occurred than was seen in trials using slaughter methods considered to be more favourable to reducing ecchymosis. In a further experiment, which inadvertently included two pregnant does, an entire buck and ten castrates, there appeared to be an association between sex type and ecchymosis. From the data obtained from these previous studies it was apparent that physiological changes in fallow deer associated with sex type and time of year may be important considerations in attempts to minimise the prevalence of ecchymosis.

The effect of sex type on ecchymosis expression has not been investigated in sheep, cattle or deer and only one study cited in the literature considered sex type in pigs. Burson *et. al.* (1983) compared barrows and gilt's and no effect was shown between these two sex types and ecchymosis expression.

The current experiment sought to clarify the effect of 4 stunning and exsanguination combinations comprising captive bolt and electrical stunning and thoracic stick and gash cut exsanguination, on ecchymosis at a type D abattoir where the interval between stunning and exsanguination was approximately 15 seconds. The effect of sex type on the incidence of ecchymosis was also investigated.

Extending previous studies in which blood plasma constituents were measured, samples were also collected from deer slaughtered in the current trial and analysed for circulating cortisol, testosterone and progesterone. As an indicator of pre-slaughter stress, ultimate carcass pH was also determined.

Materials and Methods

Animals

Twenty four does, twenty four entire bucks, and twenty four castrates were slaughtered in winter (June) at a type D2 abattoir which only slaughtered deer. The deer were not weighed prior to slaughter in order to minimise the potential for pre-slaughter stress to confound the results but as an indication the mean HCW of the does was 22.6kg (SEM ± 0.4), the castrates 27.4kg (SEM ± 0.5), and the bucks 27.5kg (SEM ± 0.4). All the deer originated from the same farm except 12 of the does. The does and castrates were held at the UWSH deer farm for 12 and 3 months respectively prior to the slaughter trial. The does had been synchronized for mating and at the time of slaughter were at approximately 50 days gestation. The entire bucks remained at the farm of origin until the slaughter trial due to difficulties associated with transporting bucks during the breeding season. The castrates held at UWSH were grazed as a group on a Kikuyu based pasture and fed grain supplements.

The does came from two separate mobs grazed on Kikuyu and supplemented with a high protein ration. The bucks on the original farm were grazed on Lucerne pasture and grain supplement. The does were yarded and weighed weekly as part of another trial and were consequently well habituated to handling. The castrates were not subjected to increased handling, aside from more frequent movement between paddocks than would be expected commercially, due to the relatively small size of the paddocks at the UWSH farm. The bucks were only yarded the day prior to slaughter. However, the bucks were not naive to handling and associated with the general management of the farm from where they came would have been yarded approximately four times over two years, and moved from paddock to paddock numerous times.

Transport and Lairage

The deer were yarded at the respective farms the morning prior to being transported to the abattoir where they were held in lairage overnight and slaughtered the next morning. The deer were misted in lairage which involved a fine overhead spray of water continuously over the deer. The distance to the abattoir in the case of the bucks was approximately 50 kms which took 1.5 hours. The distance from UWSH to the abattoir was approximately 152 kms which took 3 hours. Each sex group remained separated throughout transportation and lairage. Up until slaughter, each deer remained with their group until approximately 10 seconds before stunning when it was drafted from the group and moved to the restraining device. The deer had no access to food or water during the 20 hours prior to slaughter.

Allocation to Treatment Groups

The experiment was designed as a Latin square split plot. The sex types (castrates, bucks, and does) were the whole plots and a factorial combination of stunning and exsanguination methods (slaughter treatment) were the sub plots. The slaughter treatment groups comprised:
1) Electrical stunning and gash cut exsanguination (ESGC);
2) Electrical stunning and thoracic stick exsanguination (ESTS);
3) Penetrative captive bolt stunning and gash cut exsanguination (CBGC); and
4) Penetrative captive bolt stunning and thoracic stick exsanguination (CBTS).

As the does used in the trial had originated from two different farms, each treatment group was allocated three does from each farm source.

Stunning and Exsanguination Techniques

Electrical stunning was at 250 volts for 2 seconds. Captive bolt stunning, thoracic stick and gash cut exsanguination were as previously described. Exsanguination was initiated between 15 and 20 seconds after stunning. The deer exsanguinated by thoracic stick method were hoisted onto the dressing out rail prior to exsanguination, while the gash cut deer were bled in lateral recumbency.

Measurements

The rate of blood loss was measured as previously described. Blood samples were collected at exsanguination and circulating cortisol, progesterone and testosterone concentrations were measured. The uterus of each doe was examined during evisceration procedures to determine pregnancy status. Ultimate pH was measured (*M. longissimus dorsi*) approximately twenty four hours after slaughter using a standard pH meter which compensated for temperature (TPS LC80-A, Jenkins, Queensland, Australia). Ecchymosis was graded using the boning room method.

Statistical Analysis

Total loin and round ecchymosis scores were used to indicate ecchymosis incidence and severity. Data were square root transformed because of heterogeneity of variance and analysed using analysis of variance (Genstat 5, 4.1, 1997). Logistic regression was used to determine the effect of sex type on ecchymosis incidence (Minitab 12.1, 1995). Relationships between sex type and; cortisol, peak stun current, and ultimate pH, were analysed using ANOVA (Minitab 9, 1995).

Results

Ecchymosis

The results showed a significant difference (p= 0.03) between the gash cut and thoracic stick methods of exsanguination with respect to the amount of ecchymosis present in the loins and rounds. The mean total loin and round ecchymosis score for the gash cut treatment group was 3.36 (SEM ± 0.58), which was significantly higher (p= 0.03) than that for the thoracic stick treatment group which had a mean total ecchymosis score of 1.83 (SEM ± 0.44).

Stunning method was also observed to have an effect on ecchymosis expression with captive bolt stunning producing significantly more ecchymosis (p= 0.05) than electrical stunning. The mean total loin and round ecchymosis scores for the captive bolt and electrically stunned deer were 3.11 (SEM ± 0.53) and 2.08 (SEM ± 0.51) respectively.

When only carcasses with a total loin and round ecchymosis score greater than 1 were considered to be affected by ecchymosis, the incidence with respect to each of the 4 slaughter treatment groups went from highest to lowest in the order of captive bolt stunning and gash cut exsanguination, captive bolt stunning and thoracic stick exsanguination, electrical stunning and gash cut exsanguination, and electrical stunning and thoracic stick exsanguination (

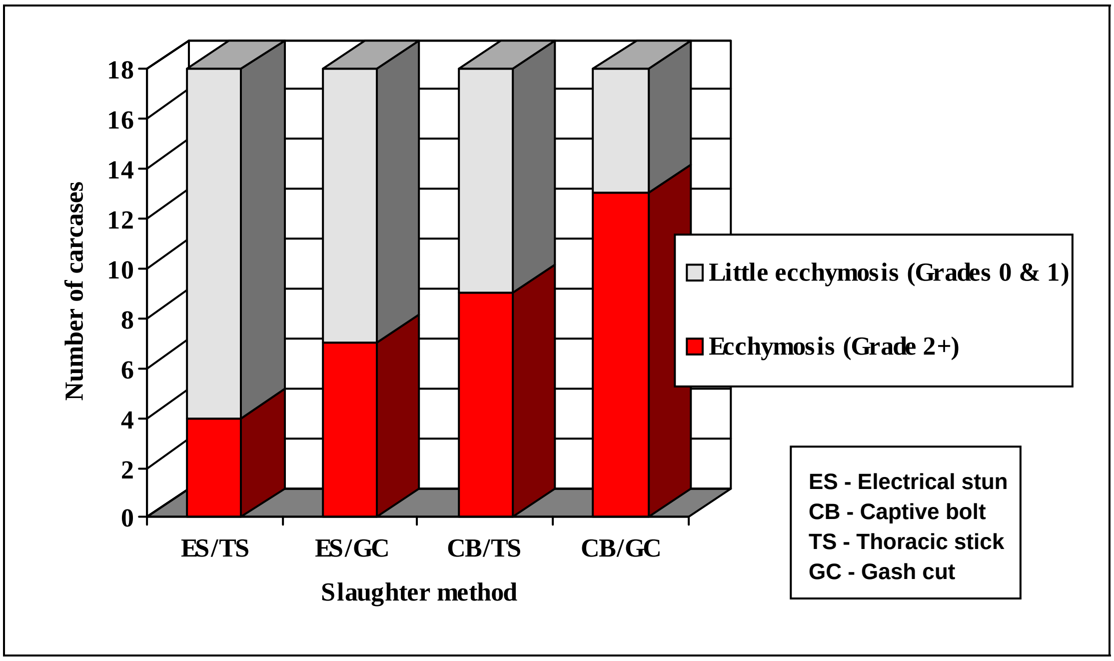
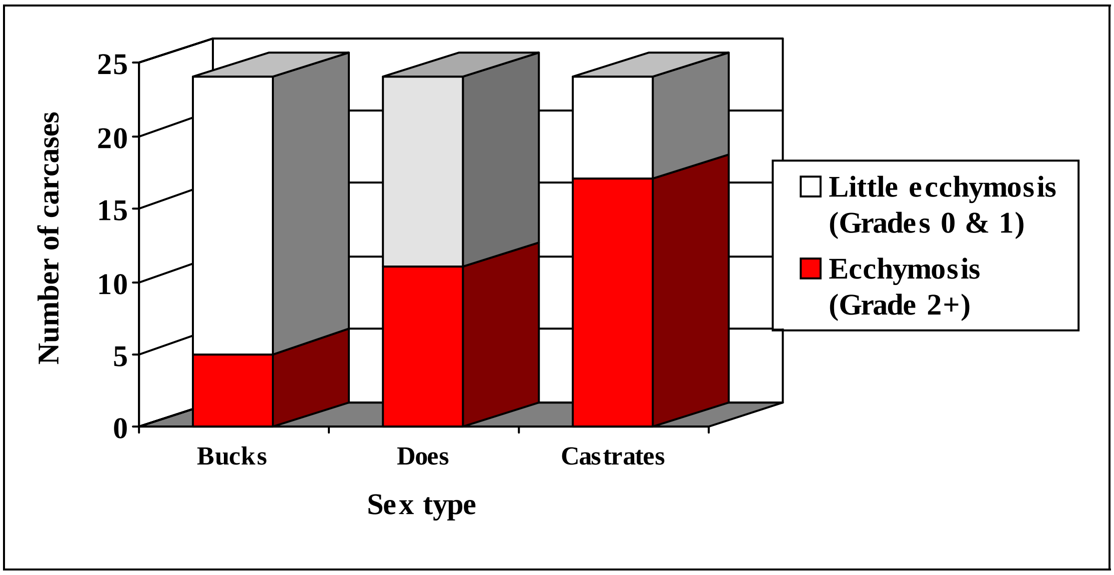


Figure 7.1: The incidence of ecchymosis in deer slaughtered by four combinations of stunning and exsanguination methods comprising electrical and captive bolt stunning and gash cut and thoracic stick exsanguination.

There was no sex type by slaughter treatment interaction of significance observed from the results with respect to ecchymosis incidence. However, using the total loin and round ecchymosis scores, when little or no ecchymosis (grade 0 or 1) was compared with some ecchymosis ($\geq$ grade 2) using logistic regression, both castrates (p= 0.002) and does (p= 0.06) were significantly different from bucks, with castrates 9.8 times more likely to have some ecchymosis than bucks, and does 4.2 times more likely (Figure 7.20).

Figure 7.2: The incidence of ecchymosis in bucks, castrates and does in a trial comparing slaughter methods at a type D2 abattoir.



There were no significant interactions observed to affect the incidence of ecchymosis, between slaughter treatments and circulating progesterone, testosterone, cortisol concentrations, or ultimate pH.

Cortisol, Testosterone, and Progesterone Levels

The mean circulating testosterone concentrations for bucks and castrates were 0.59 *ng/mL* (SEM $\pm$ .02) and 0.44 *ng/mL* (SEM $\pm$ 0.02) respectively. The mean circulating progesterone concentration for the does was 3.9 *ng/mL* (SEM $\pm$ 0.20). All of the does were determined pregnant from the examination of each uterus at evisceration.

Sex type was shown to have a significant ($p= 0.001$) effect on circulating cortisol concentrations measured at the time of slaughter with bucks having lower concentrations than castrates and does. The mean circulating cortisol concentrations for bucks, castrates, and does were 49.14 *ng/mL* (SEM $\pm$ 2.65), 77.91 *ng/mL* (SEM $\pm$ 4.69), and 74.81 *ng/mL* (SEM$\pm$ 5.40) respectively.

Electrical Stunning

The mean peak stun current for the bucks, does, and castrates combined was 1.37 amps. (SEM $\pm$ 0.07). Although not significant, the mean peak stun current appeared to be affected by sex type, with the mean peak stun current being highest for the bucks at 1.51 amps (SEM $\pm$ 0.09), and lowest for the does at 1.28 (SEM $\pm$ 0.09). The mean peak stun current for the castrates was 1.37 (SEM $\pm$ 0.14).

Ultimate pH

Sex type was shown to have a significant effect on ultimate pH ($p< 0.001$) measured at the *M. longissimus dorsi*, approximately 24 hours after slaughter. Ultimate pH was highest in the bucks with a mean pH of 5.66 (SEM $\pm$ 0.02), and lowest in the does which recorded a mean pH of 5.54 (SEM $\pm$ 0.01). The mean ultimate pH for the castrates was 5.59 (SEM $\pm$ 0.01).

Discussion

As was observed in previous trials involving relatively homologous groups of deer with respect to age, liveweight and pre-slaughter history conducted at a type B abattoir, the thoracic stick method of exsanguination reduced the incidence of ecchymosis compared with the gash cut method. This occurred regardless of stunning method and despite the interval between stunning and exsanguination in the current study being between 15 and 20 seconds as opposed to 5 seconds at the type B abattoir. Clearly the thoracic stick method of exsanguination should be incorporated into all deer slaughter systems to reduce the incidence of ecchymosis.

With respect to the effect of stunning method on ecchymosis expression, given that the interval between stunning and exsanguination in the current experiment was between 15 and 20 seconds the results of the current study were consistent with those observed in a previous trial, which compared the effect on ecchymosis expression of two stunning methods and long and short intervals between stunning and exsanguination. In the current experiment the captive bolt method of stunning caused a greater amount of ecchymosis to occur in comparison with electrical stunning. Reasons for this occurrence are likely related to the dynamics of blood distribution, which was affected by methods of stunning and the interval between stunning and exsanguination.

From previous trials it became apparent that bucks and does may have been less susceptible to ecchymosis than castrates. The results of the current experiment substantiated this, showing clearly that at the time of year that the trial took place (winter) castrates had a greater pre-disposition to ecchymosis than does, and does had a greater pre-disposition than bucks. This result may help to explain the sporadic occurrences of ecchymosis observed between and within mobs of deer slaughtered using the same methods commercially.

Consistent with all previous trials, in the current experiment there was no relationship observed between circulating progesterone, testosterone, or cortisol concentrations and ecchymosis incidence on an individual animal basis. The cortisol levels at slaughter for the castrates and does used in the current experiment were within the range previously observed in slaughter trials conducted at the UWSH abattoir, and samples collected from fallow deer slaughtered commercially. However the mean cortisol level recorded for the bucks used in the current trial was lower than observed in any other trial. The high ultimate pH observed in the carcasses of the bucks from the current study in comparison with the does and castrates perhaps reflected a greater level of physical activity prior to slaughter associated with normal aggressive behaviour common to the period of the rut. The low incidence of ecchymosis and high pH observed in the bucks used in the current study reflected the results of a previous trial in which bucks were slaughtered in the autumn period when rutting behaviour was greatest. With respect to the proposition that pre-slaughter stress pre-disposes animals to ecchymosis it was apparent from the aforementioned observations that while high pH may be a symptom of pre-slaughter stress of a physical nature it was not symptomatic of the type of stress associated with high incidences of ecchymosis. It may be possible that emotional stress and anxiety, rather than physical stress, may pre-dispose animals to ecchymosis and with respect to the bucks used in the current experiment, the low cortisol levels observed may have been symptomatic of low levels of emotional stress or 'fear' prior to slaughter. This in turn was perhaps manifest in the lower incidence of ecchymosis in comparison with the castrates and does.

7.5 Conclusions

As discussed in the introduction to this chapter, at the commencement of this study (1996) there was only one type B export abattoir available to slaughter fallow deer from Queensland, NSW, Victoria, and South Australia for export from Australia, and that abattoir slaughtered all deer according to Muslim custom which involved head only electrical stunning followed by the gash cut method of exsanguination. However, towards the end of the current study (1998) a number of new abattoirs, some said to be deer specialist abattoirs (Type D2) and others built initially to slaughter ratites (Type D1), commenced slaughtering deer. In addition to this the existing type B abattoir and another that had previously slaughtered fallow deer were also being made available for non-Muslim slaughter.

At both the type B and type D abattoirs four combinations of stunning and exsanguination methods comprising head only electrical and captive bolt stunning, and thoracic stick and gash cut methods of exsanguination could possibly be used for the slaughter of fallow deer. However, while the 4 combinations of stunning and exsanguination methods were available at both types of abattoir the associated slaughter systems were still considerably different with respect to the method of restraint used and the minimum interval between stunning and exsanguination that could be achieved. At the type B abattoirs the interval was consistently less than 5 seconds, while at the type D abattoirs it was seldom less than 15 seconds and often as long as 30 seconds. Hence, the current study investigated the effect of the 4 slaughter method combinations and the interval between stunning and exsanguination on the incidence of ecchymosis in fallow deer.

Previous research in sheep and deer had suggested captive bolt stunning to be associated with a lower incidence of ecchymosis than electrical stunning (Spencer, 1979; Kirton *et. al.*, 1980; Grogan, 1998). However, these studies were all conducted in type B abattoirs where the interval between stunning and exsanguination was less than 5 seconds. This result was not able to be confirmed in the current study because when either captive bolt or electrical stunning were used in conjunction with a short interval between stunning and exsanguination such a low incidence of ecchymosis occurred regardless of stunning method that a comparison was not possible. It was apparent that much larger numbers of animals would be needed to observe any potential effect.

In the current study, when deer exsanguinated after either a short (< 15 seconds) or a long (> 25 seconds) interval between stunning and exsanguination were compared, when the interval between stunning and exsanguination was greater than 15 seconds the captive bolt method of stunning caused a greater incidence of ecchymosis than electrical stunning, and this result was consistent with previous work in pigs (Burson *et. al.*, 1983).

It was concluded from the results of the current study that the slaughter systems most conducive to the reduction of ecchymosis in fallow deer would be those of the type B abattoirs with the incorporation of the thoracic stick method of exsanguination and perhaps captive bolt stunning. With respect to the slaughter of fallow deer, the reference to ‘deer specialist abattoirs’ should only be considered as indicating that no other species of livestock are slaughtered therein. It would appear that while type D abattoirs comprise lairage facilities purpose built for deer they are essentially only adaptations to cattle slaughter systems which have been shown in the current study to be inappropriate for the slaughter of fallow deer.

The effect of exsanguination method was also investigated in the current study and regardless of the interval between stunning and exsanguination or the method of stunning used, the thoracic stick method was shown to reduce ecchymosis in comparison with the gash cut method. This result was consistent with previous studies and clearly the thoracic stick method of exsanguination should replace the gash cut method in all fallow deer slaughter systems.

The results of the current study were consistent with observations of previous experiments in which it was apparent that castrates, does and bucks may have each had a different predisposition to ecchymosis. It was shown in the current experiments that castrates were most likely to be affected by ecchymosis followed by does, with bucks least likely to be affected by ecchymosis. Also associated with sex type, measurements of cortisol, progesterone and testosterone were made and as was observed in previous trials, no relationship existed between these hormones and ecchymosis incidence on an individual animal basis. On a sex type basis however it was interesting to observe in the current study that the low incidence of ecchymosis which occurred in the bucks was associated with the lowest levels of cortisol recorded in the current and numerous previous studies. Ultimate pH was also measured in the current study and again a sex type effect was observed with the highest levels occurring in the bucks. This was proposed to reflect physical stress pre-slaughter associated with rutting behaviour. Accordingly, it was proposed that when discussing the effect of pre-slaughter stress on ecchymosis, distinction should be made between physical stress as manifested in measures such as pH, and emotional stress or 'fear' which may require a different means of measurement. In a previous study in which bucks were slaughtered during the rut using methods considered favourable to the production of ecchymosis, consistent with the current experiment while pH was extremely high, very little ecchymosis occurred. However, cortisol levels at slaughter in the bucks from the previous study were not as observed in the current study, rather they were in the middle of the range observed in other sex types in numerous other trials. Further work should determine the efficacy of cortisol as a measure of the type of emotional stress or 'fear' that may pre-dispose animals to ecchymosis expression.

It would appear from the results of the current study that even when there was no slaughter treatment effect observed on the incidence of ecchymosis, on an individual animal basis some of the animals were affected more than others. While this can now be explained in part with regard to studies comprising different sex types, individual animal variations were still observed to occur between animals of the same sex type, perhaps suggesting that some animals may be physiologically more pre-disposed to ecchymosis than others. If this were so, small numbers of deer such as those used in many of the current experiments would make conclusions difficult to draw, especially where the effects of treatments were very subtle. As was indicated previously with regard to the effect of stunning method on ecchymosis in slaughter systems with intervals of less than 5 seconds between stunning and exsanguination, such factors may only be able to be investigated economically in the commercial environment using large numbers. Unfortunately, attempts made during the current study to conduct experiments in commercial abattoirs were largely unsuccessful due to the actions of the commercial venison processors involved.

8. Anatomical distribution of ecchymosis

8.1 Introduction

This study was commissioned by the deer industry of Australia following numerous reports of venison being condemned by venison processors due to high incidences of ecchymosis. The Australian Quarantine Inspection Service (AQIS) was the organisation responsible for the inspection and passing of meat for export from Australia. The AQIS guidelines with respect to muscle tissue exhibiting ecchymosis (EMO. 222.2), required that affected tissue must be trimmed from the carcass and condemned as unfit for human consumption.

AQIS inspection of animals being processed for human consumption occurred at a number of points in the processing chain including:

1. an ante-mortem inspection at the abattoir prior to slaughter;
2. a postmortem inspection of the visceral organs after removal;
3. an inspection of the whole carcass prior to storage, involving muscles visible within the thoracic and abdominal cavities and the external surfaces of the carcass; and
4. where carcasses were further processed, individual commercial cuts were inspected in the boning room.

Under this inspection regime condemnation of venison due to ecchymosis only occurred in the boning room, although occasional reports were received from AQIS inspectors of high incidences of ecchymosis detected in muscles visible during the whole carcass inspection on the slaughter floor at the abattoir.

From the abattoir, some carcasses were moved to a boning room where they were broken down into standard commercial cuts as previously described (Appendix 2), and at that point ecchymosis may have been detected and meat condemned. Whether meat was inspected before or after the denvering process (often referred to as denuding) differed between boning rooms and this affected considerably the amount of meat condemned. This lack of standardisation also made anecdotal reports from commercial operators regarding ecchymosis incidence unreliable. During the denvering process the inter-muscular fat and selvage surrounding the muscle or group of muscles which comprised a commercial cut was removed. This process may also remove almost all visible ecchymotic lesions in cuts Often the denvering process also removed almost all visible ecchymotic lesions in cuts of meat with grade 2 ecchymosis or less (Falepau & Mulley, unpublished).

During this study (1996-1998) a significant number of whole carcasses, as opposed to packaged commercial cuts were being exported from Australia (Falepau, unpublished). The inspection of these carcasses for ecchymosis was limited to the whole carcass inspection carried out on the slaughter floor at the abattoir. In previous studies with sheep where only the whole carcass was inspected by visual examination of external surfaces (Kirton & Woods, 1976) muscles affected by ecchymosis that were not visible externally were missed. Anecdotal reports from boning rooms where deer carcasses were broken into commercial cuts (Sheridan, 1996, Thonick, 1997;

McLure, 1998) indicated that this was also apparent in deer. While some people in the Australian deer industry saw the inability to detect ecchymosis in whole carcasses exported from Australia as undesirable, some venison processors refrained from boning carcasses so that their venison would not be inspected and possibly condemned from export.

An inspection and grading system that would provide an indication of the extent to which whole carcasses were affected by ecchymosis would enable processors to withhold carcasses suspected of having extensive ecchymosis from being exported to markets sensitive to the meat blemish. Alternatively it would also enable processors to better discriminate which carcasses they wished to bypass the boning room. Identification of "marker" tissues such as visceral organs, which were inspected closely under current meat inspection guidelines, that may constitute a consistent indicator of ecchymosis in more economically valuable skeletal muscles, would assist in the marketing of consistently high quality venison. It is also possible that ecchymosis in the skeletal muscles of the body cavity or in those visible on the external surface of the whole carcass may also act as indicators of ecchymosis in other skeletal muscles. Identification of reliable indicators of ecchymosis in commercially valuable skeletal muscles would assist significantly the QA program for venison in Australia, particularly with respect to venison from fallow deer.

As previously reviewed in the literature, ecchymosis was studied in a number of livestock species including; sheep, cattle, and pigs. In none of those studies was the complete anatomical dissection of carcasses reported. Rather, the determination of whether various factors investigated in experiments had an effect on ecchymosis incidence were based on the inspection of only those muscle surfaces visible on the whole carcass or commercial cuts into which carcasses of the particular species were commonly broken down (Burson *et. al.*, 1983; Pearson *et. al.*, 1977; Kirton *et. al.*, 1978; Blackmore, 1979; Restall, 1980-81; Calkins *et. al.*, 1981; Kirton & Frazerhurst, 1983; Lambooy & Sybesma, 1988; Smulders *et. al.*, 1989). Consequently, comparisons of the results from different experiments, particularly involving different species, may be of negligible value.

In sheep, which were commercially broken down into hind legs, loin section, and forequarter, few muscles were revealed that could not already be inspected on a whole carcass basis. Accordingly, most researchers in New Zealand investigating ecchymosis in sheep (Pearson *et. al.*, 1977; Kirton *et. al.*, 1978; Kirton *et. al.*, 1980-81a and 1980-81b; Kirton & Frazerhurst, 1983) determined ecchymosis incidence on a whole carcass basis using a grading system developed by the Meat Industry Research Institute of New Zealand (MIRINZ) which involved a 5 point scale, with 0 indicating no ecchymosis and 5 indicating severe ecchymosis. As such, the inspection was based on externally visible muscles such as the intercostals, abdominals, and diaphragm, where the latter was not removed during evisceration. In some studies the gall bladder, heart and duodenum were also inspected and were shown to be affected by slaughter treatments similarly to skeletal muscles (Kirton *et. al.*, 1978; Kirton *et. al.*, 1980-81b; Kirton & Frazerhurst, 1983). However, while the aforementioned visceral organs generally showed the same relationship to slaughter treatments as the skeletal muscles and could therefore be used to measure responses to treatments, the actual incidence of ecchymosis in the organs was often considerably different to that in the skeletal muscles. Accordingly, although the studies did not intend to determine the organs as indicators of more widespread skeletal muscle ecchymosis, the results showed none of them to be useful for that purpose. Kirton & Woods (1976) went further in one study to determine the extent of ecchymosis throughout the carcass by slicing whole carcasses from end to end at 1cm intervals and counting ecchymotic lesions. Ecchymosis was shown to be equally distributed between left and right sides of the carcass and the worst affected regions of the carcass were said to be the diaphragm, the flap, and areas of the ribs and loin away from the midline (backbone). In severely affected carcasses, ecchymosis was found in the eye muscle, the fillet, leg and shoulder (Kirton & Woods, 1976).

In pigs, Burson *et. al.* (1983) determined ecchymosis incidence by inspecting muscle surfaces visible on the wholesale shoulder, ham, and loin during commercial boning. On this basis, they found an association between slaughter method and ecchymosis distribution, with the incidence of ecchymosis in the rump being greater in captive bolt stunned animals bled after a delayed interval, in comparison with electrically stunned pigs. Burson *et. al.* (1983) also inspected the diaphragm and showed it to be a good indicator of more widespread ecchymosis throughout the other commercial cuts. In other work on pigs, Lambooy & Sybesma (1988) only investigated ecchymosis in the shoulders of pigs, finding the three muscles most frequently affected to be the *M. supraspinatus, M. triceps brachii,* and *M. caput humeri.*

Of all the species including sheep, cattle, pigs, and deer, the specifications of the commercial cuts into which the carcasses were broken down appeared to be most alike between deer and cattle, using the AUS-MEAT specifications for deer (Appendix 2) and the specifications for beef described by Butterfield & May (1966) for comparison. Accordingly, studies concerning ecchymosis in cattle (Lambooy, 1986; Smulders *et. al.*, 1989) referred to ecchymosis in commercial meat cuts or specific muscles which were similar to those in which ecchymosis in venison was of concern because it could be visibly detected by a customer. The commercial boning out of deer carcasses generally required the dissection of the hindquarter into commercial cuts consisting of only one or two individual muscles. In one report on ecchymosis in beef the individual muscles including the longissimus dorsi, *M. semimembranosus, M. iliopsoas, M. gastrocnemius, M. gracilis, M. rectus femoris,* and flexor muscles were put forward as being particularly predisposed to the occurrence of ecchymosis in cattle (Lambooy, 1986). Charles (1960) reported observations of ecchymosis in cattle but in the majority of cases it was confined to the muscles of the forequarter and only in extreme cases did it occur throughout the carcass.

No work has previously investigated the anatomical distribution of ecchymosis in deer. A grading chart however, was developed to facilitate the quantification of the extent and severity of cases of ecchymosis in deer (appendix 1). The chart was based on the loin (*M. longissimus dorsi)* and round (*M. vastus lateralis*) commercial cuts. The loin and round were suggested to be the most commonly affected commercial meat cuts in deer, although this was based on anecdotal evidence alone. The chart was used in throughout the current study to indicate the severity of ecchymosis in any muscles of the carcass.

During the course of this study a number of visits were made to abattoirs which slaughtered deer commercially in order to study in detail the slaughter process. While at these abattoirs, whole venison carcasses were inspected to determine the presence of ecchymosis using the left round as an inspection site. The left round was chosen as it was possible to reveal the superficial surface of the *M. vastus lateralis* being one of the muscles of which the round was comprised, by the removal of the *M. tensor fasciae latae*. In the cold and cramped conditions encountered within abattoir chillers, this technique enabled the rapid appraisal of large numbers of carcasses and clearly had the potential to be incorporated in commercial inspection systems. While general observations suggested the round to be a reliable indicator of ecchymosis in other parts of the carcass no studies of sufficient detail had been conducted to support this.

In this study, data collected from numerous trials conducted to investigate factors associated with ecchymosis were used to determine patterns in the anatomical distribution of ecchymosis in fallow deer. The development of a commercially practicable inspection system was considered imperative to guaranteeing the quality of venison exported from Australia. In respect to data collected in subsequent experiments, at commercial abattoirs and boning rooms, and from work reported in other species where only a limited number of muscles of the carcass could be inspected, a better understanding of the distribution of ecchymosis throughout the carcass was also a prerequisite to comparing results or considering the commercial significance of research findings.

8.2 The anatomical distribution of ecchymosis in the skeletal muscles of fallow deer

As discussed in the introduction, much of the previous work investigating factors associated with ecchymosis was based on the inspection of a number of pre-selected skeletal muscles and in some cases visceral organs. In general, the choice of which muscle or organ to inspect appeared to be based on either the degree to which the carcasses of particular species were dissected commercially, or the commercial significance of ecchymosis occurring in the particular animal part. For this reason it was difficult to determine the most relevant sites of a deer carcass upon which an inspection system should be based. From a review of the literature, no previous studies had investigated in detail relationships between ecchymosis incidence in different skeletal muscles or organs of the fallow deer. The following section presents data recorded from the complete dissection of a number of fallow deer carcasses in order to identify the particular muscles most frequently affected by ecchymosis.

Materials and Methods

Data source

Fallow deer carcasses were retrieved from 4 trials conducted at the UWSH abattoir. In each trial the deer were allocated to treatment groups involving electrical stunning at either of 4 voltages (150, 200, 300, or 400) for a duration of either 1, 2, or 3 seconds. The deer were exsanguinated approximately 8 seconds after stunning using the gash cut method. No treatment effect on the incidence of ecchymosis was observed in any of the trials.

Dissection Method

Venison carcasses (n=8) were chilled for at least 24 hours and then longitudinally halved. Each half was dissected into a 3-rib hindquarter and a 10-rib forequarter, and then into component muscle, bone, and fat. Dissection of individual muscles was carried out systematically according to the method described by Butterfield & May (1966). Bone and fat were discarded and each muscle was inspected visually for ecchymotic lesions. The score recorded to indicate the extent to which each muscle was affected by ecchymosis was allocated according to the RIRDC ecchymosis grading chart (appendix 1).

Statistical Analysis

No statistical analysis of the data was required.

Results

Table 8.1: Ecchymosis scores for muscles dissected from the hindquarters of fallow deer carcasses.

Name of muscle (Listed in order of dissection)	**Ecchymosis scores** (Each consecutive pair of columns represents the left and right side of the same carcass. Blank squares indicate a score of 0)																**Number of muscles affected** (Number of carcasses affected)
M. tensor fasciae latae		1															**1** (1)
M. biceps femoris	2	2		2	1	1	1	3	3	3	1	3	1			1	**13** (8)
M. gluteus medius	3	3	3	2	2	1	2	2	2	4	3	3	1	3			**14** (7)
M. vastus lateralis	1	1	2	1	2	1	3	3	2	1	1	2	2	4	3	2	**16** (8)
M. gluteus accessorius	1	2	2				3	1				1					**6** (4)
M. gluteus profundus	1	1	1				2	1				1					**6** (4)
M. rectus femoris	1	3		1	2	1	3	3	1	1	1	1	2	3			**13** (7)
M. semitendinosus	1	3	1	1			1	1		1	1	4					**9** (5)
M. gracilis						1				1	3	2					**4** (3)
M. semimembranosus	1	1	2	2	1	1	2	1	2	1	3	4	1	2		1	**15** (8)
M. adductor femoris	1		1				1	1	1	1		1	2	1		1	**10** (7)
M. gastrocnemius et m. soleus					1		1			2	1	1	2	2			**7** (5)
M. flexor digitorum superficialis (s. plantaris)													1	1			**2** (1)
M. pectineus				2			1			1		3	1				**5** (5)
M. sartorius							1										**1** (1)
M. gemellus											4						**1** (1)
M. quadratus femoris				1													**1** (1)
Mm. obturatorii externus et internus								1			1		2				**3** (3)
M. vastus medialis							1	4				1	4	4	1	2	**8** (4)
M. vastus intermedius	1				1	1	4	4				1	3	1	2	1	**10** (6)
M. articularis genu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
*Extensor group***							4	1									**2** (1)

Name of muscle (Listed in order of dissection)	**Ecchymosis scores** (Each consecutive pair of columns represents the left and right side of the same carcass. Blank squares indicate a score of 0)																**Number of muscles affected** (Number of carcasses affected)
M. peronaeus longus				1								1					**2** (2)
M. extensor digiti quarti propius (pedis)																	*
M. tibialis anterior																	*
*M. tibialia posterior****																	*
*M. flexor digitorum longus (pedis)****	2	2							1								**3** (2)
*M. flexor hallucis longus****	2	2			1									1			**4** (3)
M. popliteus																	*
M. psoas minor																	*
M. psoas major		1					1		1								**3** (3)
M. quadratus lumborum									1								**1** (1)
M. illiacus				1													**1** (1)
M. latissimus dorsi												2					**1** (1)
M. trapezius thoracis																	*
M. serratus dorsalis caudalis																	*
M. iliocostalis (s. longissimus costarum)											1	1		1			**3** (2)
M. longissimus dorsi	1	1	2	3	1	1	1	2	2	2	3	2	3	4	2	2	**16** (8)
M. spinalis dorsi													1		1	1	**3** (2)
Mm. multifidi dorsi									2	3			2	3	1		**5** (3)
M. obliquus externus abdominis			1	3	1	1											**4** (2)
M. retractor costae					1		1										**2** (2)
M. obliquus internus abdominis					3	2		1	2	3	2	2	3	3			**9** (5)
M. transversus abdominis						1			2	2	2	2	3	2			**7** (4)
M. rectus abdominis		1							1	2							**3** (2)
Mm. saccrococcygeal																	*
M. levator ani (s. retractor ani)																	*
Mm. intercostales externi et interni					1	1					1						**3** (2)
Mm. levatores costarum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. coccygeus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mm. intertransversarii caudae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. ischiocavernosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. praeputialis caudalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. praeputialis cranialis (s. protractor praeputii)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 8.2: Ecchymosis scores for muscles dissected from the forequarters of fallow deer carcasses.

Name of muscle (Listed in order of dissection)	**Ecchymosis scores** (Each consecutive pair of columns represents the left and right side of the same carcass. Blank squares indicate a score of 0)																**Number of muscles affected** (Number of carcasses affected)
M. cutaneus trunci et omobrachialis																	*
M. trapezius cervicalis																	*
M. trapezius thoracis																	*
M. deltoideus																	*
M. infraspinatus			1	1			1							1			**4** (3)
M. triceps brachii (caput laterale)							1					2					**2** (2)
M. teres minor																	*
M. triceps brachii (caput longum)																	*
M. tensor fasciae antibrachii																	*
M. extensor carpi radialis																	*
M. extensor digiti tertii proprius																	*
M. extensor digitorum communis																	*
M. extensor digit quarti proprius																	*
M. extensor carpi ulnaris (s. ulnaris lateralis)																	*
M. adductor pollicis longus (s. extensor carpi obliquus)																	*
M. omotransversarius																	*
M. rhomboideus																	*
M. serratus ventralis cervicis			1														**1** (1)
M. serratus ventralis thoracis			1														**1** (1)
M. pectoralis profundus				1													**1** (1)
M. pectoralis superficialis			1														**1** (1)
M. supraspinatus	1				1	1	2	3	1			1	3	2	2	2	**11** (7)
M. biceps brachii																	*
M. teres major																	*
M. coracobrachialis																	*
M. subscapularis								1									**1** (1)
M. brachialis								1								1	**2** (2)
M. brachiocephalicus															1		**1** (1)
M. triceps brachii (caput mediale)																	*
M. flexor carpi radialis																	*
M. flexor carpi ulnaris																	*
M. flexor digitorum sublimis																	*
M. flexor digitorum profundus																	*
M. anconaeus																	*
M. serratus dorsalis cranialis																	*
M. scalenus dorsalis																	*

Name of muscle (Listed in order of dissection)	**Ecchymosis scores** (Each consecutive pair of columns represents the left and right side of the same carcass. Blank squares indicate a score of 0)																**Number of muscles affected** (Number of carcasses affected)
M. cervicohyoideus (s. omohyoideus)																	*
M. longissimus cervicis							1							1		1	**3** (3)
M. splenius																1	**1** (1)
M. sternocephalicus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. scalenus ventralis																	*
M. longissimus et atlantis																	*
M. intertransversarius longus																	*
M. semispinalis capitis (s. complexus)																	*
M. rectus capitis dorsalis major													1				**1** (1)
M. obliquus capitis caudalis																1	**1** (1)
M. rectus thoracis (s. transversus costarum)																	*
M. transversus thoracis																	*
M. longus colli																	*
Mm. multifidus cervicis																	*
M. obliquus capitis cranalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. rectus capitis ventralis (s. rectus capitis ventralis minor)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. rectus capitis lateralis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. rectus capitis dorsalis minor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diaphragm					1	1			3	3	3	2				1	**7** (4)

Legend:
* equal to zero.
- not scored because muscle was either too small for inspection or only a small fragment remained on the dressed carcass.
** Extensor group muscles comprise; M. *peronaeus tertius, M. extensor digitorum longus, M. extensor digitorum brevis, M. extensor digiti tertii proprius (pedis).*
*** The flexor digitorum profundus (pedis) arises by the heads of these three muscles.

A comparison of the hindquarter (Table 8.1) and forequarter (Table 8.2) ecchymosis scores showed a greater amount of ecchymosis occurring in the hindquarter. Of the total 752 hindquarter muscles inspected 217 (29%) were affected by ecchymosis. In contrast only 38 (0.05%) of the 800 forequarter muscles inspected were affected by ecchymosis.

Of the forequarter muscles, the *M. supraspinatus* and diaphragm were the most frequently affected with ecchymosis in these muscles occurring in 11 and 7 respectively, out of the 16 carcass sides. The next most frequently affected muscle of the forequarter was the *M. infraspinatus* which was affected in 4 of the sides, each time recording a score of 1.

Of the hindquarter muscles, the *M. longissimus dorsi* and *M. vastus lateralis* were affected in all 16 of the carcass sides. The next most frequently affected muscle was the *M. semimembranosus* with 15 muscles affected, followed by the *M. biceps femoris, M. gluteus medius,* and *M. rectus femoris* which were affected in 13 of the possible 16 carcass sides. The *M. adductor femoris* and *M. vastus medialis* were affected in ten sides, and the *M. semitendinosus* and *M. obliquus internus abdominis* in nine. The *M. vastus intermedius* was affected in 8 carcass sides. Of the 36 remaining muscles of the hindquarter, 27 of them were affected in at least one of the sides but no more than seven.

Discussion

From the dissection of eight fallow deer carcasses it was clear that the muscles of the hindquarter and loin were more frequently affected by ecchymosis compared with those of the forequarter. Unfortunately, the most frequently affected muscles of the carcass were also those which sell at retail for the highest price per kilogram. Of the hindquarter muscles these included:

- *M. longissimus dorsi* of which 76%[3] of the striploin is comprised;
- *M. vastus lateralis* which is visible on the superficial surface of the round and the *M. rectus femoris* which combine to comprise 68% of the round[4];
- *M. semimembranosus* and *M. adductor femoris* which together comprise 75 % the topside;
- *M. biceps femoris* and *M. semitendinosus* which are either sold separately or together to comprise 77% of the silverside; and
- *M. gluteus medius*, which combined with 20% of the *M. biceps femoris*, makes up 73% of the rump.

Of the forequarter muscles, two of the three most frequently affected muscles were also the most valuable, the *M. supraspinatus* and *M. infraspinatus* which can be sold individually as 'blade'.

A commercially relevant whole carcass ecchymosis inspection system for fallow deer would require that ecchymosis incidence in the "marker" tissue be consistent with ecchymosis in the most frequently affected commercial cuts. The remainder of the current study investigated the potential of various body parts as indicators of ecchymosis in the loin, round and other commercial meat cuts of the hind leg.

8.3 The distribution of ecchymosis in the hindquarter, loin and shoulder

The commercial boning out of deer carcasses generally required the dissection of the hindquarter into commercial cuts consisting of only one or two individual muscles. Unfortunately, previous results showed the muscles of the hindquarter appeared to be particularly predisposed to ecchymosis.

During this study a number of whole venison carcasses were inspected at commercial abattoirs to determine the presence of ecchymosis using the left round as an

[3] Proportions expressed as percentages of commercial cuts extrapolated from work on the ox, Butterfield & May, 1966.
[4] Sometimes referred to as 'knuckle' or 'thick flank'.

inspection site. The left round was chosen as it was possible to reveal the superficial surface of the *M. vastus lateralis*, being one of the muscles of which the round is comprised, by the removal of the *M. tensor fasciae latae*. While general observations suggested the round to be a reliable indicator of ecchymosis in other parts of the carcass no studies of sufficient detail had been conducted to support this. In subsequent trials results were often based on loin and round ecchymosis scores for ease of analysis, thus the current study investigated the these muscles also as indicators of ecchymosis throughout other hind leg primals.

Materials and Methods

Data Source

Ecchymosis scores for the loins, hind leg primals, and one shoulder muscle determined using the boning room method of inspection described previously, were combined for analysis to determine relationships between muscles regarding both incidence and severity of ecchymosis. The data was retrieved from the trials that reported electrical stunning methods, and combinations of stunning and slaughter methods.

Results

When there was little or no ecchymosis (Grade 0 or 1) in the left round (n= 208) of a carcass, between 87 % and 99 % of the time there was no ecchymosis worse than grade 1 in either of the loins, rumps, silversides, *M. semitendinosus*, topsides, or *M. supraspinatus*. However, of the carcasses where ecchymosis greater than grade 1 was exhibited in the left round (n= 81), between 36 % and 56 % of the time there was no ecchymosis greater than grade 1 in the other muscles. In carcasses where the left round exhibited ecchymosis of a score greater than grade 1, there was almost always (85 % to 95 % of the time) some (> grade 0) ecchymosis in the other round, both loins, and both rumps (Table 8.3).

Table 8.3: The number of carcasses exhibiting ecchymosis in the commercially valuable hind leg primals, *M. supraspinatus*, and loins (grade 0 or 1, > 0, > 1) expressed as a percentage of the carcasses which exhibited ecchymosis (grade 0 or 1, > 1) in the left round.

	Left round ecchymosis score		
	0 or 1	> 1	> 1
	n= 208	n= 81	n= 81
Comparative muscle ecchymosis score	0 or 1	> 1	> 0
Right round	90.87	74.07	95.06
Left loin	90.87	56.79	88.89
Right loin	86.54	60.49	93.83
Left rump	90.87	72.06	91.36
Right rump	89.90	56.79	92.59
Left silverside*	99.04	51.85	85.19

Right silverside	97.60	44.44	86.42
Left *M. semitendinosus*	97.12	30.00	63.75
Right *M. semitendinosus*	95.67	27.50	66.25
Left topside	98.08	33.33	36.33
Right topside	95.67	24.69	69.14
Left *M. supraspinatus*	95.36	23.08	74.36
Right *M. supraspinatus*	95.24	23.08	57.69

When ecchymosis greater that grade 1 was exhibited in the left round (n= 81) there was almost always (98 % of the time) some (> grade 0) ecchymosis exhibited in at least one of the loins or rumps, and one of the silversides or topsides. However the relationship was not as strong (69 % to 84 %) when only ecchymosis greater than grade 1 in the other hind leg primals or loins was counted (Table 8.4).

Table 8.4: The number of carcasses exhibiting ecchymosis in any of the loins or rumps, and silversides or topsides (grade 0 or 1, > 0, > 1) expressed as a percentage of the carcasses which exhibited ecchymosis (grade 0 or 1, > 1) in the left round.

	Left round ecchymosis score		
	0 or 1	> 1	> 1
Number of carcasses	n= 208	n= 81	n= 81
Comparative muscle ecchymosis score	0 or 1	> 1	> 0
Loins and rumps	79.81	83.95	97.53
Silversides & topsides	89.42	69.14	97.53

In a number of trials in the current study the loins and rounds only were used to determine ecchymosis incidence in throughout the carcass. Of the 123 carcasses which exhibited ecchymosis greater than grade 1 at least one of the loins or rounds, 86 % also had some ecchymosis in the left rump and right rump, and 94 % had ecchymosis in at least one of the other hind leg primals. These proportions diminished (52 %, 49 %, and 57 % respectively) when only ecchymosis greater than grade 1 was counted for all muscles (Table 8.5).

Table 8.5: The number of carcasses exhibiting ecchymosis in the silversides or topsides, left rump, and right rump (> 0, > 1) expressed as a percentage of the carcasses which exhibited ecchymosis > 1 in the left round.

	Any loin or round ecchymosis score	
	> 1	> 1
Number of carcasses	n= 123	n= 123
Comparative muscle ecchymosis score	> 0	> 1
Left rump	86.18	52.03
Right rump	86.18	48.78
Any silverside or topside	93.50	56.91

Discussion

The results of the current study indicated that the left round could be used as an indicator of the presence of ecchymosis in either the loins or the other hind leg primals with considerable accuracy when carcasses were boned out prior to the inspection of the muscles. When a carcass did not exhibit ecchymosis greater than grade 1 in the left round it would not be expected to exhibit ecchymosis greater than grade 1 in any of the other muscles. If a carcass exhibited ecchymosis greater than grade 1 in the left round there was a greater than 85 % chance that some (> grade 1) ecchymosis also occurred in each of the loins and silversides, but generally only a greater than 50 % chance that the ecchymosis was greater than grade 1.

When little or no ecchymosis (grade 0 or 1) occurred in the left round there usually none in either the *M. semitendinosus*, topsides, or *M. supraspinatus* muscles, and when the left round did have ecchymosis greater than grade 1, generally less than 30 % would have ecchymosis greater than grade 1 in the other muscles, however as many as 85 % would have some (> grade 0).

With respect to subsequent trials where the results were based on the presence of ecchymosis in the loins and rounds only, the current experiment would suggest the results from those trials to be indicative of ecchymosis occurring in each of the rumps in approximately 86 % of the carcasses, and in at least one of the other hind leg primals in 93 % of the carcasses.

As the results of the current study would suggest, the only means of accurately determining the incidence of ecchymosis in the valuable commercials cuts of the venison carcass including the loin and hind leg primals, was by the removal and inspection of those muscles via boning. On that basis fallow deer venison should not be exported on a whole carcass basis particularly those carcasses processed at abattoirs using methods demonstrated in the current study to cause high incidences of ecchymosis.

Where processors choose not to refrain from exporting whole carcasses, the inspection of the round in situ could be considered a relatively accurate means of determining ecchymosis incidence in the other commercial cuts on a whole carcass basis and could be adopted by the industry. The method of inspecting the round in situ involved the removal of the portion of the *M. tensor fasciae latae* which covered the *M. vastus lateralis* which was then visible by superficial examination. In the current experiment ecchymosis in the round was inspected after its removal from the carcass however, the results were based on either little or no ecchymosis (grade 0 or 1) or ecchymosis greater than grade 1. This was because generally, ecchymosis of grade 1 or less detected after the removal of the round would not be easily visible via the examination of the round, as this usually took place in the chiller at an abattoir where poor lighting precluded as accurate an examination as could occur in the boning room. Thus in the current study, ecchymosis recorded in the round greater than grade 1 could be considered as grade 1 via the in situ method of examination and on this basis, in the commercial situation where there was any ecchymosis detected in the left round in situ there would be some ecchymosis in at least 89 % the loins, other rounds, and rumps and in as many as 85 % of each of the other hind leg primals upon closer examination at boning.

Unfortunately, it is possible that some vendors would choose to export those carcasses with ecchymosis greater than grade 1 in the round knowing that if they were to bone them out they would also have to condemn up to 90 % of each of the other cuts if all ecchymosis was condemned, and up to 70 % of some of the other cuts even if only ecchymosis greater than grade 1 was condemned. Given that AQIS requirements are that no ecchymotic meat be exported consideration should be given with respect to modifying the current inspection practices for deer.

8.4 The heart and lungs as indicators of ecchymosis in skeletal muscles

The meat inspection system in Australia requires the inspection of the visceral organs including the heart and lungs of all animals slaughtered for human consumption. The inspection of these organs by a qualified meat inspector takes place after the viscera is removed from the slaughtered animal. A number of studies on ecchymosis in lambs, cited in the general introduction to this section, included the inspection of the heart, gall bladder and duodenum, and although slaughter treatments had an effect on ecchymosis in these organs, the results when compared to the data collected for the whole carcass did not show them to be good ‘marker” tissues for ecchymosis in skeletal muscles.

The current study investigated the relationship between ecchymosis in the heart, lungs and skeletal muscles of fallow deer.

Materials and Methods

Heart and Lung Grading

The hearts and lungs of fallow deer from 4 slaughter trials were inspected for ecchymosis and allocated a score using the RIRDC ecchymosis grading chart (appendix 1). The organs were inspected shortly after removal from the carcass at the abattoir. Excess blood was wiped from the organs prior to inspection.

Data Source

The 4 slaughter trials from which data was retrieved included two trials investigating the effect of electrical stunning method on ecchymosis in castrates and bucks respectively, and two trials involving does which investigated the effect of stunning method and the interval between stunning and exsanguination on ecchymosis.

In the castrate and buck trials the deer were allocated to treatment groups involving electrical stunning at either of 4 voltages (150, 200, 300, or 400) for a duration of either 1, 2, or 3 seconds. The deer were exsanguinated approximately 8 seconds after stunning using the gash cut method. The castrate trial was conducted in the last week of August (winter) and the buck trial was conducted two months later. No treatment effect on the incidence of ecchymosis was observed in either the castrate or the buck trial.

The two trials involving the fallow does were 2 x 2 factorial designs with treatment groups comprising electrical or captive bolt stunning with long (30 seconds) or short

(6 seconds) intervals between stunning and exsanguination using the thoracic stick method. The first trial was conducted in the second week of September (spring) and the second trial on the last day of November. A significant ($p < 0.01$) slaughter treatment effect was shown. Captive bolt stunning and delayed exsanguination caused higher incidence of ecchymosis than either of the stunning methods combined with the short interval between stunning and exsanguination. In addition to this, more ecchymosis was observed overall in the skeletal muscles in trial 1 than in trial 2.

Data Analysis

The heart and lung data from all trials was analysed using ANOVA (Minitab 9, 1995) to determine if there was any slaughter treatment effect on the incidence of ecchymosis. Count data for the buck and castrate trials was also analysed using the Chi-square test (Minitab 9, 1995) to determine the difference between the trials with respect to ecchymosis incidence in the heart and lungs. No analysis of the data was required to determine relationships between heart and lung ecchymosis and ecchymosis in the skeletal muscles for either the doe, castrate or buck trials.

Results

Castrates and Bucks

The data from the trials investigating electrical stunning were previously analysed for slaughter treatment effect on ecchymosis incidence in skeletal muscles and there was found to be no treatment effect. Similarly to the skeletal muscles, there was no observed treatment effect on ecchymosis incidence in the hearts and lungs of either the bucks or the castrates.

Table 8.6: Heart, lung and skeletal muscle ecchymosis score for castrates.

Body part	Ecchymosis scores					Mean ecchymosis score	SEM$\pm$	Percent affected
	0	1	2	3	4			
Heart	3	13	3	1	2	1.364	0.233	86
Lung	10	9	2	0	1	0.773	0.207	56
Left round	7	5	4	5	1	1.455	0.277	68
Right round	2	12	3	2	3	1.636	0.259	91
Left loin	2	11	3	4	2	1.682	0.250	91
Right loin	4	9	2	4	3	1.682	0.290	82

Table 8.7: Heart, lung, and skeletal muscle ecchymosis scores for bucks.

Body part	Ecchymosis scores					Mean ecchymosis score	SEM±	Percent affected
	0	1	2	3	4			
Heart	19	2	0	0	0	0.0952	0.0656	10
Lung	17	1	2	1	0	0.571	0.272	19
Left round	10	5	3	3	0	0.952	0.244	52
Right round	5	7	5	4	0	1.381	0.234	76
Left loin	3	6	10	0	2	1.619	0.234	86
Right loin	2	10	3	6	0	1.619	0.223	90

There was a significant difference ($p < 0.001$) between trials with respect to the incidence of ecchymosis in both the hearts and lungs, with a lesser incidence of ecchymosis in the hearts and lungs of the bucks (heart 10%, lung 19%) than in the castrates (heart 86%, lung 56%). Overall, neither the heart nor lung were observed to be efficient indicators of ecchymosis in the skeletal muscles (Table 8.6 and Table 8.7).

Does

Previous analysis of the skeletal muscle ecchymosis score data showed a significant ($p < 0.01$) slaughter treatment effect on ecchymosis in the skeletal muscles of the does. There was also more ecchymosis exhibited in the skeletal muscles of the carcasses from the first trial than in those from the second trial (Table 8.8 and Table 8.9).

Table 8.8: Heart, lung, and skeletal muscle ecchymosis scores for does from trial 1.

Body part	Ecchymosis scores					Mean ecchymosis score	SEM ±	Percent affected
	0	1	2	3	4			
Heart	22	0	0	0	0	0	0	0
Lung	9	6	0	0	7	1.545	0.376	59
Left round	15	3	0	3	1	0.727	0.273	32
Right round	15	2	2	2	1	0.727	0.265	32
Left loin	16	4	0	1	1	0.500	0.226	27
Right loin	15	3	3	0	1	0.591	0.225	32

Table 8.9: Heart, lung, and skeletal muscle ecchymosis scores for does from trial 2.

Body part	Ecchymosis scores					Mean ecchymosis score	SEM ±	Percent affected
	0	1	2	3	4			
Heart	22	0	0	0	0	0	0	0
Lung	13	7	1	1	0	0.545	0.171	41
Left round	20	1	1	0	0	0.136	0.100	9
Right round	19	1	2	0	0	0.227	0.130	14
Left loin	16	6	0	0	0	0.273	0.097	27
Right loin	18	3	0	1	0	0.273	0.150	19

No ecchymosis was observed in any of the hearts from the does in either trial and the heart could therefore be excluded from consideration as indicators of ecchymosis in skeletal muscles.

In trial 1 the incidence and severity of ecchymosis in the lungs was considerably greater than in any of the skeletal muscles and in trial 2 the same occurred although the difference was not as great. Overall the lungs could not be considered an efficient indicators of ecchymosis in the skeletal muscles.

Overall, more ecchymosis was observed to have occurred in the lungs of the does from trial 1 than trial 2 (Table 8.8, Table 8.9, Table 8.10, and Table 8.11) and this was consistent with the ecchymosis scores for the skeletal muscles (Table 8.8 and Table 8.9).

The data from each trial were similar with respect to the slaughter treatment effect on ecchymosis incidence in the lungs (Table 8.10 and Table 8.11). Combining the data from both trials, there was a significant ($p = 0.001$) slaughter treatment effect shown, with all of the lungs from the does electrically stunned and exsanguinated after the delayed interval exhibiting ecchymosis. In contrast, only one of the lungs from the does, which were captive bolt stunned and exsanguinated after the short interval exhibited ecchymosis.

Table 8.10: Ecchymosis scores showing treatment effect on lungs of does from trial 1.

Treatment	Lung ecchymosis scores					Mean ecchymosis score	± SEM	Percent affected
	0	1	2	3	4			
CB/D	5	0	0	0	1	0.667	0.667	17
CB/S	1	4	0	0	0	0.800	0.200	80
ES/D	0	0	0	0	6	4.000	0.000	100
ES/S	3	2	0	0	0	0.400	0.245	40

Table 8.11: Ecchymosis scores showing treatment effect on the lungs of does from trial 2.

Treatment	Lung ecchymosis scores					Mean ecchymosis score	± SEM	Percent affected
	0	1	2	3	4			
CB/D	5	0	0	0	0	0	0	0
CB/S	4	2	0	0	0	0.333	0.211	33
ES/D	0	3	1	1	0	1.600	0.400	100
ES/S	4	2	0	0	0	0.333	0.211	33

Discussion

A slaughter treatment effect was observed with respect to ecchymosis incidence in the lungs of the does which was in complete contrast to that which was observed with respect to ecchymosis in the skeletal muscles. The least affected slaughter treatment group with respect to ecchymosis in the lungs was the group slaughtered using the captive bolt and exsanguinated after the delayed interval. In contrast, this was the worst affected group with respect to ecchymosis in the skeletal muscles. The worst effected slaughter treatment group in both doe trials with respect to ecchymosis in the lungs was the group electrically stunned and exsanguinated after the delayed interval. Again the ecchymosis in the skeletal muscles of this group was no worse than that which occurred in either of the other treatment groups.

A simple explanation for this phenomena might be based around blood distribution as potentially influenced by the method of stunning, and interval between stunning and exsanguination. Logically, for ecchymosis to occur in the tissue of a particular part of the anatomy blood must be present in that tissue. It is possible in the case of the aforementioned doe trials, that the tonic phase of greater than 5 seconds duration induced by the electrical stun, which has been previously described, caused a larger proportion of blood to distribute away from the skeletal muscles to other parts of the anatomy such as the lungs, than occurred in the captive bolt stunned deer where the tonic phase was approximately half the duration. The incidence of ecchymosis in the lungs of the electrically stunned delayed exsanguination treatment group was then exacerbated by the delay in exsanguination, but as a consequence of the blood not having returned to the skeletal muscles the incidence therein was minimal. In contrast, of all the treatment groups, the longest period of time for blood to redistribute back to the skeletal muscles and away from the lungs, was in the captive bolt stunned deer of the delayed exsanguination interval group. Hence the ecchymosis in the skeletal muscles of this group was the worst and in the lungs the least of any group.

The results showed a greater incidence of ecchymosis overall in the lungs of the does from the first trial in compared with the second trial. This reflected the observations made with respect to ecchymosis in the skeletal muscles also. The first trial was conducted in the second week of September when the does were at approximately five months gestation whereas the second trial was conducted in the last week of November when the does were nearing parturition. It is possible, considering the previous discussion regarding blood distribution in relation to slaughter method, that the presence of a foetus also influenced the dynamics of blood distribution in a similar fashion to the lungs. In this instance, the blood requirement of the foetus, via the placenta, associated with the second trial may have been greater than that in the first trial. In the does of the second trial less blood may therefore have been available for redistribution to the muscles or lungs than was available in the does of the first trial. Hence the greater amount of lung and skeletal muscle ecchymosis in the first trial than the second.

The primary aim of the work presented in this section was to consider the heart and lung as indicators of ecchymosis in the more valuable skeletal muscles of the fallow deer carcass. From the results, the incidence of ecchymosis in the hearts was inconsistent with the incidence in the loins and Rounds in the carcasses of the does and bucks. In the does none were affected by ecchymosis in the heart, in contrast to some of the skeletal muscles being affected in 30% of the carcasses. In the bucks, less than 10% of the deer that had ecchymosis in the skeletal muscles had ecchymosis in the hearts. The castrates were the only sex type to show a similar incidence of ecchymosis in both the hearts and skeletal muscles. In the commercial situation, mobs of fallow deer sent for slaughter can comprise deer of all three sex types and often both castrates and buck in particular. On this basis the use of an ecchymosis inspection system that was relevant for only one sex type would not be practicable.

Of the castrates slaughtered which exhibited ecchymosis in the skeletal muscles only just over 50% were accounted for by ecchymosis occurring in the lungs. In the bucks only 20% of the carcasses that exhibited ecchymosis in the skeletal muscles were accounted for by ecchymosis occurring in the lungs. In both groups of does the incidence of ecchymosis in the lungs was almost twice that which occurred in some of the skeletal muscles. On this basis the lungs were not considered effective indicators of ecchymosis incidence in the skeletal muscles of fallow deer.

8.5 The internal body cavity muscles as indicators of ecchymosis in skeletal muscle

Most of the previous studies on ecchymosis in sheep were based on the inspection of the externally visible muscle surfaces of the whole carcass including the intercostals, abdominals, and diaphragm, where the latter was not removed during evisceration (Pearson *et. al.*, 1977; Kirton *et. al.*, 1978; Kirton *et. al.*, 1980-81a and 1980-81b; Kirton & Frazerhurst, 1983). None of these studies in sheep investigated specifically the relationship between ecchymosis in these muscles, and others in which ecchymosis was considered commercially deleterious in deer. In work on ecchymosis in pigs Burson *et. al.* (1983) inspected the diaphragm as well as other muscles of the carcass and showed the diaphragm to be a good indicator of more widespread ecchymosis throughout the carcass and Thornton & Gracey (1974) considered the diaphragm to be the most frequently affected skeletal muscle in beef and sheep carcasses.

One of the aims of the current study was the development of a commercially practicable inspection system for ecchymosis in deer. The skeletal muscles external to the thoracic and abdominal cavity, while able to be inspected superficially were often covered by fat and would therefore generally be excluded as potential inspection sites. Within the abdominal and thoracic cavity a number of muscles were easily visible superficially, including the tender loins comprised mainly of the *M. psoas major,* the intercostal muscles, the abdominal muscles, and the diaphragm.

From the results presented earlier, the tender loins and intercostals could be excluded as indicators of ecchymosis on the basis that out of 16 carcass sides dissected, while all of the loins and rounds were affected by ecchymosis only 3 of the M. *psoas major* and 3 of Mm. intercostales externi et interni were affected, and in each of these cases the ecchymosis was only of grade 1 severity. In contrast ecchymosis occurring in the *M. obliquus internus abdominis, M. transversus abdominis,* and *M. rectus abdominis* combined accounted for 10 of the carcass sides and the diaphragm 7. The abdominal muscles, as visible by superficial examination rather than complete dissection, and the diaphragm could be considered as potential indicators of ecchymosis in the other skeletal muscles of the carcass.

The current study investigated the incidence of ecchymosis in the diaphragm and abdominal muscles of fallow deer carcasses from a number of sources including both commercial deer slaughter abattoirs and research trials. Due to the number of different data sources used each data set is documented as a separate section including both a description of the data source and the results.

Materials and Methods

Ecchymosis Grading

In all cases the diaphragm and abdominal muscles were inspected no sooner than 20 hours after slaughter using a torch to illuminate the inside of the body cavity. Reference to the abdominal muscles throughout this section refers more specifically to the portions of the *M. obliquus internus abdominis, M. transversus abdominis*, and *M. rectus abdominis* visible on the whole carcass without separation. Under these conditions the most visible abdominal muscles were the *M. transversus abdominis* and *M. rectus abdominis*, with much of the *M. obliquus internus abdominis* being covered by the tender loins (*M. psoas major*). Similarly, ecchymosis in the diaphragm refers to that observed on the distal superficial surface of the left or right diaphragm muscles.

The scoring of ecchymosis in skeletal muscles other than those in the body cavity was carried out using either the boning room or chiller grading methods previously described previously. The method used will be nominated in each of the descriptions of the data sets that follow.

Commercial Type D1 Abattoir

Materials and Methods

The left and right diaphragm and left round were inspected and ecchymosis scores recorded from 124 fallow deer slaughtered at a type D1 commercial abattoir using captive bolt stunning and the gash cut method of exsanguination. The deer were slaughtered in the second week of April. Sex type was not determined by visual observation but the venison processor believed them to be a mixture of bucks and castrates. Blood samples were collected immediately after exsanguination from 37 randomly selected deer and analysed for circulating cortisol and testosterone levels. The left round was scored for ecchymosis using the chiller grading method. For each carcass inspected only the highest of the left and right diaphragm ecchymosis scores was recorded.

Results

The mean circulating testosterone concentration for the 37 deer from which blood samples were collected was 0.45 *ng/mL* (SEM ± 0.02). The mean circulating cortisol concentration was 71.22 *ng/mL* (SEM ± 3.79). When the individual assay data was plotted according to testosterone levels there was no relationship between testosterone and cortisol levels to be observed.

Of the 124 carcasses inspected, 69 % exhibited ecchymosis in either the left or right diaphragm muscles while only 28 % of the carcasses were affected by ecchymosis in the left round (Table 8.12). 34 of the 35 carcasses, which exhibited ecchymosis in the round also exhibited ecchymosis in the diaphragm. However, 52 of the carcasses exhibited ecchymosis in the diaphragm but did not exhibit ecchymosis in the round. 37 carcasses had no ecchymosis in either the diaphragm or the round (Table 8.13Table).

Table 8.12: Diaphragm and round ecchymosis scores for 124 fallow deer slaughtered at a commercial type D1 abattoir.

Body part	Ecchymosis scores					Number of carcasses	Per cent affected
	0	1	2	3	4		
Diaphragm	38	41	25	16	4	124	69
Left round	89	23	11	1	0	124	28

Table 8.13: Cross tabulation showing ecchymosis scores for round and diaphragm of 124 fallow deer slaughtered at a type D1 commercial abattoir.

		Diaphragm ecchymosis score				
		0	**1**	**2**	**3**	**4**
Round ecchymosis score	**0**	37	1	0	0	0
	1	35	6	0	0	0
	2	12	10	2	1	0
	3	5	6	5	0	0
	4	0	0	4	0	0

Commercial Type B Abattoir

Materials and Methods

The diaphragm, abdominal, and left round ecchymosis scores were recorded from 220 fallow deer slaughtered at a type B commercial abattoir using electrical stunning and the gash cut method of exsanguination. The sex type of the deer was unknown. The left round was scored for ecchymosis using the chiller grading method. For each carcass inspected only the highest of the left and right diaphragm and abdominal muscle ecchymosis scores was recorded.

Results

26 % of the 220 carcasses inspected had ecchymosis in the left round compared with 35 and 36 % having ecchymosis in the diaphragm and abdominal muscles respectively. 48 % of the carcasses had ecchymosis in either the diaphragm or abdominal muscles (Table 8.14).

Table 8.14: Diaphragm, abdominal, and round ecchymosis scores for 220 fallow deer slaughtered at a commercial type B abattoir.

Body part	Ecchymosis scores					Number of carcasses	Per cent affected
	0	1	2	3	4		
Diaphragm	143	65	10	2	0	220	35
Abdominal	141	66	13	0	0	220	36
Dia. & Abd.*	114	53	34	15	4	220	48
Left round	162	51	6	1	0	220	26

* highest recorded score

When ecchymosis was counted as either present or not present, rather than by grade, of the 58 carcasses that exhibited ecchymosis in the round 76% of them also had ecchymosis in the diaphragm and 66% in the abdominal muscles. Combining both the diaphragm and abdominal muscles as “marker” tissues, 86% of the carcasses with ecchymosis in the round were accounted for. Approximately half of the 162 carcasses that did not have ecchymosis in the round did have ecchymosis in the diaphragm or abdominal muscles (Table).

Table 8.15: Cross tabulation of ecchymosis scores for round, diaphragm and abdominal muscles of 220 fallow deer slaughtered at a type B commercial abattoir.

		Ecchymosis present in indicator muscles					
		Diaphragm		Abdominal		Dia. & Abd.*	
		Yes	No	Yes	No	Yes	No
Ecchymosis is present in round	Yes	44	14	38	20	50	8
	No	33	129	41	121	56	106

* highest recorded score used

Commercial Type D2 Abattoir (Research Trial)

Materials and Methods

The ecchymosis scores for the diaphragm and abdominal muscles were recorded for 72 deer slaughtered as part of the current study in a trial conducted at a type D2 abattoir involving four different slaughter methods comprising electrical and captive bolt stunning and gash cut and thoracic stick methods of exsanguination. The group of deer slaughtered comprised equal numbers of bucks, castrates, and does. The trial was conducted in June when the does were at approximately 2.5 months gestation. Loin and round ecchymosis scores referred to in the results were determined using the boning room grading method. The highest of the left and right ecchymosis scores recorded for each of the diaphragm and abdominal and abdominal muscles was used for the analysis.

Previous analysis of the data showed a significant slaughter treatment effect on ecchymosis incidence in the loin and round with both captive bolt stunning and the gash cut method of exsanguination producing more ecchymosis than electrical stunning and gash cut exsanguination. Sex type did not influence the effect of slaughter treatment on ecchymosis incidence. However, overall the does and castrates respectively were 4.2 and 9.8 times more likely to have ecchymosis than bucks.

Statistical Analysis

ANOVA (Minitab 9, 1995) was used to determine if there was a slaughter treatment or sex type effect on ecchymosis expression in the diaphragm and abdominal muscles.

Results

The incidence of ecchymosis for the loin, round and the diaphragm muscles was similar and ranged from 36 to 44% with the diaphragm affected in 39% of the carcasses. 26% of the carcasses were affected in the abdominal muscles (Table 8.16).

Table 8.16: Diaphragm, abdominal, and round ecchymosis scores for 72 fallow deer slaughtered at a commercial type D2 abattoir.

Body part	Ecchymosis scores					Mean ecchymosis score (SEM±)	Per cent affected
	0	1	2	3	4		
Diaphragm*	44	22	4	1	1	0.51 (0.09)	39
Abdominal*	53	16	3	0	0	0.31 (0.06)	26
Dia.& Abd.*	40	25	5	1	1	0.58 (0.09)	44
Left round	42	13	12	5	0	0.72 (0.10)	42
Right round	46	14	7	5	0	0.60 (0.12)	36
Left loin	45	19	5	2	1	0.54 (0.12)	38
Right loin	40	17	10	3	2	0.75 (0.11)	44

* highest ecchymosis score recorded

Similar to the slaughter treatment effect on ecchymosis in the loin and round shown previously, a significant slaughter treatment effect (p= 0.03) was also shown with respect to ecchymosis occurring in the diaphragm. The deer stunned using the captive bolt method recorded mean diaphragm ecchymosis scores of 0.83 (SEM ± 0.28) and 0.66 (SEM ± 0.16) when exsanguinated using the thoracic stick and gash cut methods respectively.

In contrast, the electrically stunned deer recorded mean diaphragm ecchymosis scores of 0.44 (SEM ± 0.12) and 0.11 (SEM ± 0.07) when exsanguinated using the gash cut and thoracic stick methods respectively. There was no treatment effect observed with respect to ecchymosis in the abdominal muscles. A significant sex type effect (p= 0.002) on ecchymosis in the diaphragm was observed with the castrates recording a mean ecchymosis score of 0.95 (SEM ± 0.21) compared with the does and bucks which recorded similar mean ecchymosis scores of 0.29 (SEM ± 0.09) and 0.29 (SEM ± 0.11) respectively. The abdominal muscles showed the same significant sex type effect (p< 0.001) as the diaphragm with mean ecchymosis scores of 0.75 (SEM ± 0.14) for the castrates and 0.08 (SEM ± 0.06) for both the does and the bucks.

Table 8.17: Cross tabulation of ecchymosis scores for loin, round, diaphragm and abdominal muscles of 72 fallow deer slaughtered at a type D1 commercial abattoir.

			Ecchymosis present in indicator muscles					
			Diaphragm*		Abdominal*		Dia. & Abd.*	
			Yes	No	Yes	No	Yes	No
			28	44	19	53	32	40
Ecchymosis in left round	Yes	30	19	11	16	14	22	8
	No	42	9	33	3	39	10	32
Ecchymosis is in any round or loin	Yes	46	26	20	18	28	29	17
	No	26	2	24	1	25	3	23

* ecchymosis present in either side or muscle

In 46 of the carcasses at least one of the loins or rounds was affected by ecchymosis. Using the diaphragm and abdominals as indicators of ecchymosis would have identified 29 (63%) of the 46 carcasses, and the diaphragm alone 26. The abdominal muscle used exclusively as the marker tissues would have accounted for only 18 of the 46 carcasses in which one of the loins or rounds was affected. Of the 26 carcasses which did not exhibit ecchymosis in any of the loins or rounds, 2 had ecchymosis in the diaphragm and only 1 in the abdominal muscles (Table 8.17).

Using the diaphragm and abdominal muscles combined as indicators of ecchymosis accounted for 22 of the 30 carcasses which exhibited ecchymosis in the left round, the abdominals alone accounted for 16, and the diaphragm 19 (Table 8.17).

UWSH Abattoir (Research Trials)

PART 1

Materials and Methods

Diaphragm and abdominal muscle ecchymosis scores were recorded from two slaughter trials comprising 22 does each, conducted at the UWSH abattoir in the second week of September (spring) and the last day of November. The trials were 2 x 2 factorial designs with treatment groups comprising electrical or captive bolt stunning with long (30 seconds) or short (6 seconds) intervals between stunning and exsanguination using the thoracic stick method. A significant ($p<0.01$) slaughter treatment effect was shown on ecchymosis incidence in the loins and rounds. Captive bolt stunning and delayed exsanguination causing a greater incidence of ecchymosis than either stunning method combined with the short interval between stunning and exsanguination. In addition to this, more ecchymosis was observed overall in the skeletal muscles of the does in trial 1 than in trial 2. Loin and round ecchymosis scores were determined using the boning room grading method.

Results

None of the 44 carcasses exhibited ecchymosis in the abdominal muscles and only two carcasses exhibited ecchymosis in the diaphragm. The two carcasses that exhibited ecchymosis in the diaphragm came from the first trial and they both exhibited ecchymosis in each of the loins and rounds. Seven other carcasses out of the 44 exhibited ecchymosis in the left round (Table 8.8 and Table 8.9).

PART 2

Materials and Methods

Diaphragm ecchymosis scores from the carcasses from two trials involving 23 and 26 does each were recorded. The trials were conducted at the UWSH abattoir in the second and third weeks of October (spring). The does in each trial were allocated to treatment groups in a 2 x 2 factorial design accounting for electrical and captive bolt stunning and thoracic stick and gash cut exsanguination methods. There was no treatment effect shown on the incidence of ecchymosis in the loins or rounds in either of the trials.

Results

seven of the carcasses in trial 1, and three of the carcasses in trial 2 exhibited ecchymosis in the diaphragm. 18 of the carcasses in trial 1, and nine of the carcasses in trial 2 had ecchymosis in the left round. 20 carcasses in trial 1 and 16 carcasses in trial 2 had ecchymosis in at least one of the loins or rounds (Table 8.18). All of the carcasses which exhibited ecchymosis in the diaphragm also had ecchymosis in the left round.

Table 8.18: Ecchymosis incidence in the diaphragm, rounds and loins of 49 does slaughtered in the UWSH abattoir trials investigating slaughter methods.

		Number of carcasses affected		
	Number of carcasses in trial	Diaphragm	Left round	Any loin or Round
Trial 1	23	7	18	20
Trial 2	26	3	9	16

PART 3

Materials and Methods

The diaphragms from the carcasses of deer slaughtered in 4 electrical stunning trials were scored for ecchymosis. The trials included two groups of castrates (trial 1 and 2), a group of bucks (trial 3) and a group of does (trial 4). In each trial the deer were allocated to treatment groups involving electrical stunning at either of 4 voltages (150, 200, 300, or 400) for a duration of either 1, 2, or 3 seconds. The deer were exsanguinated approximately 8 seconds after stunning using the gash cut method. The trials were conducted in the first and last weeks of August (winter), the last week of September, and the first week of November. No treatment effect on the incidence of ecchymosis was observed in any of the trials.

Results

70% of the carcasses from trials 1, 2, 3, and 4 exhibited ecchymosis in the left round and 95% exhibited ecchymosis in at least 1 of the rounds or loins (Table 8.19).

1 of the carcasses from trial 1, and 2 of the carcasses from each of trials 2 and 3 had ecchymosis in the diaphragm but none in the left round. However, all of the carcasses exhibiting ecchymosis in the diaphragm had ecchymosis in at least 1 of the loins or rounds.

Table 8.19: Ecchymosis incidence in the diaphragm, rounds and loins of castrates, bucks, and does slaughtered in the UWSH abattoir electrical stunning trials.

	Sex type	Number of carcasses in trial	Number of carcasses affected		
			Diaphragm	Left round	Any loin or round
Trial 1	Castrate	24	11	18	23
Trial 2	Castrate	22	9	15	21
Trial 3	Buck	17	9	9	17
Trial 4	Doe	23	5	18	21

Discussion

The results from the trials show that the presence of ecchymosis in the diaphragm or abdominal muscles does not always indicate the presence of ecchymosis in either the left round or loins of the same carcass. In some trials the incidence of ecchymosis in the diaphragm was twice that which occurred in the skeletal muscles. On this basis whole carcasses should not be condemned on the basis of ecchymosis being present in the diaphragm or abdominal muscles.

Excluding the carcasses from the trials conducted at the UWSH abattoir, over all the other trials combined 243 carcasses exhibited no ecchymosis in either the diaphragm or abdominal muscles. Of these carcasses, 28% exhibited ecchymosis in the left round. At worst the proportion of carcasses with no ecchymosis in the diaphragm but ecchymosis in the round was 58%, and more often it was less than 20%. This result may provide some indication of the likely incidence of skeletal muscle ecchymosis in groups of carcasses in which little or no ecchymosis is detected in the diaphragm or abdominal muscles.

8.6 Conclusions

The first step towards the development of a commercially practicable ecchymosis grading system for whole fallow deer carcasses, was to determine the most frequently and severely affected skeletal muscles. From the complete dissection of a number of fallow deer carcasses it was shown that the most frequently affected muscles of the carcass were unfortunately also those which sold at retail for the highest price per kilogram. Of the hindquarter muscles these included:

- *M. longissimus dorsi* of which 76%[5] of the striploin is comprised;
- *M. vastus lateralis* which is visible on the superficial surface of the round and the *M. rectus femoris* which combine to comprise 68% of the round[6];
- *M. semimembranosus* and *M. adductor femoris* which together comprise 75 % the topside;
- *M. biceps femoris* and *M. semitendinosus* which are either sold separately or together to comprise 77% of the silverside; and
- *M. gluteus medius*, which combined with 20% of the *M. biceps femoris*, makes up 73% of the rump.

Of the forequarter muscles, two of the three most frequently affected muscles were the *M. supraspinatus* and *M. infraspinatus*. Ecchymosis in those muscles could be of varying economic significance depending on the way in which the forequarter was processed. If processed into boneless shoulder or blade according to AUS-MEAT specifications (Appendix 2) ecchymosis may not have been visible. However, when the muscles of the blade were separated and denvered, as for boneless blade ecchymosis could have been visible.

From the results of the dissection work it was clear that specific muscles or organs used as inspection sites on a whole carcass basis to indicate more generalised ecchymosis incidence, would need to indicate as accurately as possible ecchymosis incidence in the loin, round, rump and other hind leg primals as these were the most frequently and severely affected commercial venison cuts, as well as being the most economically significant. The next step in developing an ecchymosis grading system was to consider the skeletal muscles and organs inspected under the existing meat inspection system, and determine their effectiveness as predictors of ecchymosis in the more commercially important and frequently affected hind leg primals and loin.

Hearts and lungs from deer slaughtered in four separate trials involving castrates, bucks, and does were inspected for ecchymosis. The castrates and bucks had been electrically stunned using various voltages and current duration's. There was no treatment effect on the incidence of ecchymosis in the hearts or lungs of the castrates

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[5] Proportions expressed as percentages of commercial cuts extrapolated from work on the ox, Butterfield & May, 1966.

[6] Sometimes referred to as 'round' or 'thick flank'.

or bucks and this reflected results shown with respect to the skeletal muscle ecchymosis determined previously. A higher incidence of ecchymosis was observed in the hearts and lungs of the castrates than the bucks but this was not reflected in loins or rounds. In neither the castrates nor the bucks were the heart and lungs shown to be reliable indicators of ecchymosis in the skeletal muscles.

The does for which the hearts and lungs were inspected had been slaughtered in a trial which tested the effect of either a long (25-30 seconds) or short (< 5 seconds) interval between stunning and exsanguination, following either captive bolt or electrical stunning. All the deer were exsanguinated using the thoracic stick method of exsanguination. No ecchymosis was detected in any of the hearts in either trial and the heart was therefore eliminated as an indicator of ecchymosis in the skeletal muscles.

A slaughter treatment effect was observed with respect to ecchymosis incidence in the lungs of the does which was in complete contrast to that which was observed with respect to ecchymosis in the skeletal muscles. In respect to skeletal muscle ecchymosis the incidence was highest in the captive bolt delayed exsanguination group, and lowest in the electrically stunned deer. In the lungs the opposite was observed. It was proposed that this difference was due to the electrical stun causing blood to be distributed away from the skeletal muscles and into the lungs to a greater extent than did the captive bolt method. This was related to the duration of the tonic muscular contraction. Then, because the blood was in the lungs it could not leak out of muscle blood vessels, hence less skeletal muscle ecchymosis in the electrically stunned does. Conversely, in the case of the captive bolt stunned deer, while the blood was not in the lungs it was available in the skeletal muscles to leak out of damaged muscle blood vessels in to the surrounding tissue. The longer interval between stunning and exsanguination in the captive bolt stunned group appeared to exacerbate this effect.

The results also showed a greater incidence of ecchymosis overall in the lungs and skeletal muscles of the does from the first trial compared with the second trial. The does in the first trial were at approximately five months gestation whereas the does in the second trial were nearing parturition. It was proposed that the blood requirement of the foetus, via the placenta, associated with the second trial may have been greater than that in the first trial. As a result, in the does of the second trial less blood was available for redistribution to the muscles or lungs than was available in the does of the first trial. Hence the lesser amount of lung and skeletal muscle ecchymosis in the second trial than the first.

In both groups of does the incidence of ecchymosis in the lungs was almost twice that which occurred in some of the skeletal muscles. This result reaffirmed the previous results with bucks and castrate that the lungs are not reliable indicators of ecchymosis incidence in the skeletal muscles of fallow deer.

Two points of interest arose from the results in regard to ecchymosis in the hearts and lungs discussed above. Firstly, considering the bucks and castrates were slaughtered under exactly the same conditions, except for their slaughter occurring on different days, there appeared to be a sex type effect on ecchymosis incidence in the lungs and heart, with the castrates appearing more susceptible than the bucks. A sex type effect may also be implicated in that none of the does had ecchymosis in the heart at all, despite half of them being electrically stunned as were the bucks and castrates.

On the slaughter floor, the existing protocol for inspection of the whole carcass by meat inspectors, after evisceration, consists of a brief look inside the body cavity and at that point it would be possible to determine the amount of ecchymosis in the abdominal muscles or diaphragm. The intercostal muscles and *M. psoas major*, while existing within the body cavity also, were eliminated as potential inspection sites as the intercostals, from the results of the dissection work were seldom affected by ecchymosis and the *M. psoas major* (tenderloin) was usually covered by the kidneys and kidney fat retained in the carcass.

The use of a system similar to the MIRINZ ecchymosis grading system for sheep for indicating ecchymosis incidence in valuable commercial venison cuts, using the abdominal muscles and diaphragm as sites for inspection on a whole carcass had little merit. In over half of the carcasses examined which had ecchymosis in either the diaphragm or abdominal muscles there was no ecchymosis in the left round and in some cases the loin either. Excluding the carcasses from deer slaughtered at one abattoir (UWSH), of those carcasses examined in the current study which did not exhibit ecchymosis in the diaphragm or abdominal muscles (n= 243) the proportion of carcasses which exhibited ecchymosis in the corresponding round was 28%. In the worst case it was 58% but generally it was less than 20%. This provided some indication of the incidence of skeletal muscle ecchymosis that could be expected in a consignment of carcasses that showed no ecchymosis in the body cavity inspection.

The only means of accurately determining the incidence of ecchymosis in the valuable commercials cuts of the venison carcass, including the loin and hind leg primals, was by the removal and inspection of those muscles via boning. On the basis of the results from the current study, fallow deer venison should not be exported on a whole carcass basis, particularly carcasses processed at those abattoirs using methods demonstrated in the current study to cause high incidences of ecchymosis. The results of the current study showed the round removed from the whole carcass to be a good indicator of ecchymosis in the other hind leg primals and loins in that when there was little or no ecchymosis (grade 0 or 1) in the round there was almost always little or no ecchymosis in the other cuts.

Where processors choose not to refrain from exporting whole carcasses, the inspection of the round in situ could be considered a relatively accurate means of determining ecchymosis incidence in the other commercial cuts on a whole carcass basis and could be adopted by the venison processors. The method of inspecting the round in situ involved the removal of the portion of the *M. tensor fasciae latae,* which covered the *M. vastus lateralis,* which was then visible by superficial examination. During the course of the current study hundreds of left rounds were able to be inspected at rates of up to 200 carcasses an hour using this method. In the current experiment ecchymosis in the round was inspected after its removal from the carcass however, the results were based on either little or no ecchymosis (grade 0 or 1) or ecchymosis greater than grade 1. This was because generally, ecchymosis of grade 1 or less detected after the removal of the round would not be easily visible via the in situ examination of the round, as this usually took place in the chiller at an abattoir where frost bite and poor lighting precluded the accuracy of examination that is possible in the boning room. Thus in the current study, ecchymosis recorded in the round greater than grade 1 could be considered as grade 1 via the in situ method of examination and on this basis, in the commercial situation where there was any ecchymosis detected in the left round in situ, there would be expected to be some ecchymosis in at least 89 % of the loins, other rounds, and rumps and in as many as 85 % of each of the other hind leg primals upon closer examination at boning. Obviously if such carcasses were exported whole, this would be the amount of ecchymosis observed by the buyer upon processing the carcasses overseas.

Unfortunately, it is possible that some vendors would choose to export those carcasses with ecchymosis greater than grade 1 in the round knowing that if they were to bone them out they would also have to condemn up to 90 % of each of the other cuts if all ecchymosis was condemned, and up to 70 % of some of the other cuts even if only ecchymosis greater than grade 1 was condemned. Given that AQIS requirements are that no ecchymotic meat be exported consideration should be given with respect to modifying the current inspection practices for deer to avoid this practice occurring.

The muscles affected by ecchymosis in the dissected deer carcasses were similar to those which would have been observed in badly affected sheep carcasses, whereby ecchymosis was found in the eye muscle, the fillet, leg and shoulder (Kirton & Woods, 1976). However, in less severely affected sheep carcasses, the same authors observed that the diaphragm, the flap, and areas of the ribs and loin away from the midline (backbone) were most frequently affected. This was not consistent with results in the present study on deer where in many cases where the diaphragm was not at all affected by ecchymosis there was still ecchymosis in the hind leg primals and loin. It is possible that Kirton & Woods (1976) did not find more ecchymosis in the leg primals of less severely affected sheep carcasses, because of their method of dissection whereby they sliced the carcasses into 1cm sections from end to end. As they suggested, this would not have revealed many of the ecchymotic hemorrhages which were only on the surface of the muscles and not internal. Using the dissection technique of Butterfield & May (1966) in the current study, it was likely that most ecchymotic lesions were revealed.

In pigs, Burson *et. al.* (1983) found the diaphragm to be a good indicator of ecchymosis in other muscles of the carcass. This contrasts with results from the current study including those involving the complete dissection of deer carcasses whereby 9 of the 16 diaphragm muscles inspected did not have ecchymosis, but all 16 of the individually dissected *M. vastus lateralis* and *M. longissimus dorsi,* and most of the other hind leg muscles of the same carcasses did. While this difference may be related to differences between species, it may also be related to the distinction not being made between gross dissection and inspection of commercial meat cuts and complete individual muscle dissection. In the report put forward by Burson *et. al.* (1983), while individual muscles were referred to in the results, only the inspection of the "wholesale shoulder, ham, and loin" were referred to in the materials and methods. Should the results of the aforementioned authors have been based on the later of the two dissection methods it is possible that much of the ecchymosis that may have been present in individual muscles was not detected. The finding of Lambooy & Sybesma (1988) that ecchymosis in the shoulders of pigs was most frequent in the *M. supraspinatus, M. triceps brachii,* and *M. caput humeri,* was consistent with results of the dissection of the forequarters of deer, particularly in regard to the *M. supraspinatus*.

Charles (1960) suggested that ecchymosis in cattle was most frequently confined to the muscles of the forequarter and that only in extreme cases did it occur throughout the carcass. The results of the present study on deer suggest that ecchymosis is more wide spread in affected deer carcasses, a result that agrees with Lambooy's (1986) observations that the *M. longissimus dorsi, M. semimembranosus, M. iliopsoas, M. gastrocnemius, M. gracilis, M. rectus femoris*, and flexor muscles in veal calves, were most vulnerable to ecchymosis. In particular the *M. longissimus dorsi*, *M. semimembranosus*, and *M. rectus femoris* were commonly affected in deer.

9. The effect of pre-stun restraint on ecchymosis

9.1 Introduction

The slaughter of deer in Australia was for many years, and largely still is, accommodated by abattoirs used for the slaughter of other species of livestock. In most cases fallow deer were slaughtered in facilities built for the slaughter of sheep, with the larger red deer, wapiti deer and their hybrids slaughtered on cattle chains. Case study data and anecdotal reports from processors who had deer slaughtered at these abattoirs indicated that the prevalence of ecchymosis was considerably lower in red deer than for fallow deer. This may have been due to a species specific pre-disposition to ecchymosis. However it could also have been related to the considerably different slaughter systems employed for each species.

In the case studies reported previously the lowest prevalence of ecchymosis in fallow deer was associated with a type E commercial abattoir where fallow deer were stunned by penetrative captive bolt while free standing in a knocking box. The knocking box was built specifically for deer the size of fallow deer with internal measurements of approximately 120cm in length, 35cm wide, and 90cm high. The head of the deer was allowed to protrude through a hole in the front of the box, to enable the stunner operator to hold the head for placement of the captive bolt, in the same way as previously described for the UWSH abattoir. Deer were hung and thoracic stuck within 10 seconds of stunning. It was observed with this system that just prior to stunning, all deer attempted to escape from the stunner operator by pushing back against the front door of the knocking box with the forelegs. In addition to this, the tonic phase muscular contractions induced by the stun, caused the front feet to impact against the door of the knocking box, although in using a captive bolt, the tonic phase contraction lasted only for 1 or 2 seconds. Interestingly, the only ecchymosis found in the 50 carcasses inspected was located in the shoulder muscle *M. supraspinatus*, which may have been associated with the aversive action of the deer against the stunner operator and the impact of the forelegs against the front door.

In contrast, the highest prevalence of ecchymosis in fallow deer reported in the case studies was associated with a type B abattoir, using electrical stunning and gash cut exsanguination, with deer held in a v-belt restrainer system. Based on anecdotal reports from processors, and the results from the dissection of deer carcasses, all of which were slaughtered in the same manner, ecchymosis in carcasses from type B abattoir systems was most prevalent in the loin, rump and round. The muscles associated with the loin and rump would have been active during the observed struggling of the deer in the v-restrainer prior to stunning, where the head and neck were frequently arched back. The muscles associated with the round would also have contracted violently during the tonic phase resulting from the stun. When compared with the tonic phase induced by the captive bolt used in type E abattoir systems, which generally only lasted for 1 or 2 seconds, the electrical stun used in the type B abattoir and on the deer used for the dissection work stimulated tonic muscle contractions lasting usually for more than 5 seconds and as long as 10.

The only previous work relating to the effect of restraint on the incidence of ecchymosis was by Lambooy & Sybesma (1988), who electrically stunned pigs either free standing in a pen or in a v-restrainer. The incidence of ecchymosis was greater in the pigs stunned in the v-restrainer, however only the shoulders were examined. In addition to this, unlike the deer slaughtered in the type E abattoir, the free standing pigs would not have needed to be held for placement of the captive bolt.

A number of factors may be associated with the different prevalence of ecchymosis seen in the free standing and v-restraint systems in deer and pigs. One explanation that has been put forward was that blood capillaries broke during stunning from violent muscle contractions and this was exacerbated by interactions with the restraint used on the animal (Gilbert, 1993). It is also possible however, that the greater incidence of ecchymosis in the v-restrained animals was attributed to a greater emotional stress imposed on the animal, as indicated behaviourally in the deer by the pre-stun struggling observed.

By early 1998, in addition to various abattoir types previously described, there were a number of abattoirs slaughtering deer which used a squeeze crush which could contain both red and fallow deer. Considering the markedly different degrees of restraint imposed on the deer by each of the various restraint systems available for deer slaughter, it was of interest to the current study to determine whether restraint of the animal had an effect on both the incidence and distribution of ecchymosis.

9.2 Materials and methods

Animals

10 fallow deer castrates and 1 buck aged 15 months of age, and 2 does aged over 24 months, were slaughtered in autumn (March - southern hemisphere). The does had their fawns weaned from them the week prior to slaughter but had not been mated. The number of animals was limited due to animal welfare concerns associated with the potential stress imposed on the animal from the extra restraint being used.

Slaughter Treatments

All deer were slaughtered at the UWSH abattoir and electrically stunned in the v-restraining drop floor crush previously described. The deer were assigned at random to two treatment groups. One group was subjected to extra restraint by the use of a back restraint device common on these crushes. These deer also had a leg rope tied loosely around the bottom half of the left hind leg and to the rear of the crush. This prevented the hind limb from extending cranially to its maximal potential, as normally occurs during the tonic phase induced by an electrical stun. However, the deer were still able to move the hind leg normally prior to stunning. All deer were stunned using 400v for 1 second and exsanguinated using the gash cut method approximately 10 seconds after stunning.

Measurements

Ecchymosis incidence was determined by the boning room grading method as previously described.

Statistical Analysis

Muscles were considered individually as affected or not affected by ecchymosis. Data was then analysed using the Chi-squared test (Minitab 9, 1995).

9.3 Results

Observations of ecchymosis expression in the loin, round, rump, diaphragm and abdominal muscles are shown in Table 9.1.

Table 9.1: Ecchymosis scores for fallow deer subjected to normal and extra restraint at the time of stunning.
(abd. = abdominal, diaph. = diaphragm, Cast. = Castrate)

Slaughter treatment	Ecchymosis scores										
	Left loin	Right loin	Left round	Right round	Left rump	Right rump	Left abd.	Right abd.	Left diaph.	Right diaph.	Sex type
Normal restraint group	0	0	0	0	0	0	0	0	0	0	Doe
	0	0	0	0	0	1	0	1	0	1	Doe
	3	3	3	1	2	2	3	3	2	2	Cast.
	3	2	3	1	3	3	2	2	2	2	Cast.
	4	2	1	2	2	3	2	1	0	0	Cast.
	1	1	1	1	1	1	0	2	1	1	Cast.
Extra restraint group	0	0	0	0	0	0	0	0	0	0	Buck
	3	3	0	0	0	0	0	0	0	0	Cast.
	2	2	3	1	1	1	1	3	1	0	Cast.
	0	0	0	0	0	0	0	0	0	0	Cast.
	1	1	0	0	0	1	0	0	0	0	Cast.
	4	4	0	0	3	3	2	1	0	0	Cast.
	2	0	0	0	0	0	0	0	0	0	Cast.

Sex type appeared to have an effect on ecchymosis and therefore the does and bucks were excluded from further analysis. Of the 6 deer comprising the non-restraint treatment group, 2 were does. Neither of the does exhibited ecchymosis in either of the loins, rounds or rumps, while all 4 castrates had moderate to severe ecchymosis (Grades 2, 3 and 4). The one buck in the restraint treatment group did not exhibit any ecchymosis in contrast to 5 of the 6 castrates.

Considering the castrates only, restricting the cranial extension of the hind leg (restraint group) was associated with a reduced incidence of ecchymosis in the round ($p < 0.03$), the diaphragm ($p < 0.03$) and abdominal muscles ($p < 0.06$). However, treatment did not appear to affect the incidence of ecchymosis in the loin or rump. All loins and rumps exhibited ecchymosis in the non-restraint group. In the restraint group, 4 of the 6 deer exhibited ecchymosis in the loins and 3 exhibited ecchymosis in the rumps.

9.4 Discussion

Although sex type was not thought to be an important factor in this particular study, the results indicate that differences attributed to sex type did occur, albeit that few numbers of animals are available for comparison. Interestingly, the does showed a very low incidence of ecchymosis in comparison with the castrates in the same treatment group. After reviewing the literature, only two authors had previously referred to sex type and its effect on ecchymosis expression. Burson *et. al.* (1983), compared the effect of captive bolt and electrical stunning of pigs, and the time between either of these methods and exsanguination, on ecchymosis in barrows (castrate) and gilts (females) and concluded there was no sex type effect on the expression of ecchymosis. Charles (1960) observed in cattle that ecchymosis was mainly seen in ox carcasses but very seldom in the carcasses of cows. The effect of sex type on ecchymosis expression in fallow deer was studied in detail in previous trials reported in this study, and briefly it would appear that of the three sex types, castrates and does were both more likely to get ecchymosis than bucks, but does not as likely as castrates.

Previous work in pigs showed a greater incidence of ecchymosis associated with v-restraint slaughter systems than free standing slaughter systems (Lambooy & Sybesma, 1988). As posited in the introduction to this section, this may have been attributed to a greater emotional stress being associated with the v-restraint systems than the free standing system, or increased friction between the restraint device and the animal. It was originally thought that the two treatments used in these trials would be comparable with Lambooy & Sybesma's (1988) treatments. However, from observations of the behaviour of the deer from both treatment groups during the trial, it was realised that the emotional effect of the restraint would probably have been similar between the two treatment groups, and at most, only marginally greater in the restrained group as a result of the novel experience of a rope being tied around one leg and the use of the back restraint. The hind legs of the deer were not restricted from the normal pre-stun movement associated with struggling in a v-restrainer and the friction between the restraint and the animal prior to stunning would have been similar between treatments, compared with the free-standing and v-restraint treatments in pigs (Lambooy & Sybesma, 1988). Not surprising then, the results of the current study did not reflect those of Lambooy & Sybesma (1988) and in fact if ecchymosis in the loins and rumps only was considered, the muscles of which would be functioning as the animal struggled against the v-restraint, there was a similar incidence of ecchymosis between the two treatment groups.

The incidence of ecchymosis in the rounds did differ between treatment groups, with the lesser incidence associated with restriction of the cranial extension of the left hind leg. A similar treatment effect, albeit less significant, was also seen in the diaphragm and abdominal muscles, the later of which would also have had its contraction limited by the restriction of the hind leg. From observations of the restraint treatment group, the restriction of the left hind limb in some way limited the cranial extension of the right hind limb also and perhaps as a consequence of this, there was a similar reduction in the incidence of ecchymosis in the rounds of both the left and right sides of the carcass. The reduction of ecchymosis associated with restricting the maximum extension of the hind legs, and consequently the contraction of the muscles comprising the round and abdominal region, could indicate that the super-contraction of muscle fibres, implicated by Leet *et. al.* (1977) in studies on lambs to be associated with the rupture of muscle blood vessels, may possibly only occur should maximum muscle contraction be allowed, as in the case of the non-restraint treatment group.

In order to reduce the incidence of ecchymosis, particularly that which occurs in the round, for purposes of commercial slaughter, it may be possible to design a restraint system that mechanically restricts the movement of the hind legs of deer, just after the stun induced tonic phase occurs, similar to the way in which the rope restricted the cranial extension of the hind leg in the deer slaughtered in the current trial. Obviously, any form of restraint placed on the animal before it is rendered insensible by the stun may compromise its welfare and should not be considered.

The results from the current study indicated that muscle function as a result of the stun, in some way influenced the incidence and distribution of ecchymosis, and this would help to explain the prevalence of ecchymosis in the loin, round, rump, and *M. supraspinatus* muscles of deer, shown in the work on anatomical distribution discussed earlier in this chapter. Accordingly, it may be possible that altering which muscles contract as a result of the stun may also affect the anatomical distribution of ecchymosis. Observations towards the end of this study, of deer electrically stunned in a squeeze crush, whereby they were tightly held by the sides, but could often still touch the floor showed that in some cases, the tonic extension of the fore and hind limbs was caudal as opposed to the cranial extension always previously observed in v-restrained deer. This phenomena was not investigated with regard to the effect on the anatomical distribution of ecchymosis in deer. However, observations of an experiment conducted by Grogan, (1998) may shed some light. In some 30 head only electrically stunned rats, which were wedged into a v-shaped polystyrene cradle which forced all four legs to extend caudally, tonic extension of the fore and hind limbs was always caudal and associated with this, ecchymosis was found in a number of the rat carcasses in the *M. triceps bracchii*, which serves to extend the fore limbs caudal. As shown from the dissection of deer carcasses, in only two carcass sides out of 16 did the M. triceps bracchii exhibit ecchymosis. Further work should investigate this phenomena with regard to both the role of stun induced muscle contraction in the localisation of ecchymotic hemorrhages, and the factors which influence the direction of the tonic extension of the limbs induced by the stun.

10. Deer habituation study

NB: This section is extracted from Grogan (1989) and is presented for information only.

10.1 Introduction

Due to differences in temperament between deer in the various batches of deer slaughtered at UWSH abattoir, it was considered necessary to investigate prior training and habituation of deer to management practices, and the effect this might have on expression of ecchymosis at slaughter. Cortisol level is regarded as a useful marker of stress in the live animal, and the aim of the following experiment was to maintain whether prior training of deer reduced their stress response to new situations.

The slaughter of these deer also allowed the possibility to look at various meat quality attributes in relation to keeping quality.

10.2 Methods and materials

Deer Habituation

Prepubertally castrated fallow deer (2 years, n = 6, with mean $\pm$ SEM body weight of 46.5 $\pm$ 0.6kg) were maintained at pasture on the University of Western Sydney (Hawkesbury) campus deer farm, 50km north-west of Sydney, New South Wales, Australia (lat 34^{o}S). The deer were habituated to frequent handling and blood sampling to obtain basal cortisol levels at 0900 hrs over three months (November to January). The habituation process consisted of firstly allowing the herd to wander freely between the allocated paddock and laneways that were used in the mustering process. After allowing a week for orientation the herd was mustered through the laneways which led to a purpose-built holding and weighing area.

To reduce the flight-type behaviour when moved from the holding area and into the crush, for manipulations such as weighing, bleeding, and other body measurements, deer were handled twice weekly over two months. The deer were moved into a holding area and experienced human interaction, which consisted of steady deliberate movements around the holding area.

Deer were weighed in a purpose-built crush mounted on pressure bars connected to scales (Rudweight, Guyra, NSW Australia) giving kilogram measurements in half kilogram increments. Deer were held in a crush with black cloth over the deer's eyes in order to calm restrained deer (Matthews, 1993). Blood samples were obtained via jugular venipuncture using lithium heparin treat 10mL vacutainers with 20G collection needles (Becton Dickinson and Company, Rutherford, NJ USA)

Meat Quality

At the conclusion of habituation training, deer were slaughtered at the UWSH abattoir. Heart, lung, liver, diaphragm, intercostal muscles, tender loin, *M. semimembranosus* and

M. semitendinosus were inspected for the presence of ecchymosis, in the chiller, two hours after slaughter. Loin and round joints, boned out, were evaluated for ecchymosis 24 hours post-slaughter employing the RIRDC grading chart (Tuckwell & Hubbard, 1996). Loin muscle samples were obtained between the 6th and 13th thoracic vertebrae, and neck muscle samples (*M. serratus ventralis*) were also collected. Muscle pH was recorded with a pH meter (TPSA LC80-A, Jenkins, Queensland, Australia) and colour was quantified with a Minolta Chroma metre (Minolta CR-300 series, Japan) set on the L*a*b* colour system (L*=lightness, a*=red/greeness, b*=yellow/blueness). Both pH and colour measurements were performed 24 hours after slaughter. For each animal, triplicate measurements of pH and five colour measurements per freshly cut loin surface were recorded.

Mean loin peak shearforce (kg), on samples aged for eight days at 4^{o}C, was obtained from severed 2cm x 2cm cubes with a Warner-Bratzler attachment on a texture analyser (TA-XT2 texture analyser, Stable Micro Systems, Surrey, England). Percentage moisture and fate were obtained from 12g samples of loin. Moisture was determined in quadruplet, using an air oven and fat was extracted with a petroleum spirit in a continuous soxhlet extraction system (Buchi 810 extraction apparatus, Buchi Laboritoriums-Technik AG, Postfach, Switzerland).

Vacuum packed microbial analysis of loins stored at 4^{o}C was determined by conducting a standard plate count in accordance to Australian Standards (AS 1766.2.1) over four weeks. *Pseudomonas spp.* and *Lactobacillus spp.* were also quantified over the four week period using selective media and conditions outlined in the Oxoid manual (1990). A single factor ANOVA was utilised in statistical comparisons and t-tests were employed to assess the significance of contracts and regression coefficients.

10.3 Results

After two weeks of habituation to regular handling, cortisol levels significantly changed (P.02) from initial 82.1 ± 4.3 *ng/mL* to 66.4 ± 5.3*ng/mL*. Further significant reductions of this circulating glucocorticoid was noted by week six at 54.6 ± 3.6 *ng/mL* (P<0.0002) and continued to fall (Figure 10.1). Prior to slaughter (week 20) the mean cortisol concentration was 41.5 ± 4.1 *ng/mL*.

Figure 10.1: Circulating cortisol concentrations over six weeks of habituation to handling and bleeding procedures and at slaughter (week 20).

Haemorrhage scores that were observed in the organs and muscles are presented in Tables 10.1 and 10.2 More severe haemorrhage was seen in the lung and diaphragm, than in other tissues examined.

Table 10.1: Mean±SEM haemorrhage scores of selected tissue for control and testosterone treated deer

	Tissue				
Treatment	**Lung**	**Diaphragm**	**Intercostals**	**Tender loin**	***M. Biceps femoris***
Control	2.2±0.6*	1.8±0.2	1.2±0.2	0.3±0.1	0.3±0.1

*ecchymosis score based on the RIRDC grading chart (1996) on a scale of 1 to 5;
†P<0.02, **††P<0.03**

Comparisons of ecchymosis in muscles of various sections of the carcass revealed a higher prevalence of ecchymosis in muscles of the round and loin, compared with muscles of the neck and shoulder (Table 4.2).

Table 10.2: Ecchymosis scoring (mean±SEM) of boned muscles 24 hours after slaughter for both treatments

Animal #	**Round**	**Loin**	**Neck**	**Shoulder**
38	4*	4	0	0
48	2	1	0	0
70	0	0	0	0
71	0	1	0	0
77	2	2	1	1
95	0	2	0	0
MEAN SCORE	**1.3±0.7**	**1.7±0.6**	**0.2±0.2**	**0.2±0.2**

*ecchymosis score based on the RIRDC grading chart (1996; Appendix 1)

Microbiological evaluations: All counts for all monitored micro-organisms, over four weeks, were within acceptable organoleptic limits, that is, the meat did not smell abnormal or appear spoilt. Table 9.4 presents some of the meat quality parameters measured. There were no differences in colour, shearforce on keeping quality between meat cuts with ecchymosis, and those without.

Table 10.3

Attribute	Control
pH (24h):	
M. serratus ventralis	6.16+0.08
M. L. dorsi	5.43+0.02
% Moisture	74.98+0.20
% Fat	1.09+0.20
Weight (kg)	
live	47.58+0.88
HCW	23.98+0.46
% dress	50.43_0.75
Shearforce (kg)	
M. serratus ventralis	17.74+0.74
M. L. dorsi	2.14+0.05
Colour	
M. serratus ventralis	
*L**	35.60+0.26
*a**	15.51+0.27
*b**	-0.6+0.46
M. L. dorsi	
*L**	29.11+0.27
*a**	18.65+0.29
*b**	0.78+0.23

†measurements are from *M. L. dorsi* unless specified.

10.4 Discussion

A marked reduction in typical 'flighty' behaviour associated with deer was evident after four weeks of bi-weekly handling. This was also mirrored by the significant reduction in total circulating cortisol by week 4 (figure 9.1). A number of studies have provided considerable evidence that cortisol values in a number of species, including deer, increase in response to stress. A less stressful treatment has been correlated to significantly lower mean cortisol values compared to a greater stress treatment (Shaw and Tume, 1992; Cooper *et. al.*. 1995; Morton *et. al.*. 1995; von Borell, 1995; Pedersen, 1996).

Deer not accustomed to husbandry practices and their surroundings are often difficult to handle and may injure themselves on fences and handling yards during muster. This may lead to injuries including broken limbs resulting in significant stock losses. Husbandry conditions and practices may alter circulating cortisol levels, such as splitting or combining groups.

In the present study cortisol levels continued to drop and remained low, even at slaughter (week 20) when deer were subjected to transport and overnight lairage, prior to slaughter. It is proposed that habituation of stock to a range of stressors enabled the deer to cope more effectively and rapidly when faced with a new challenge. Practically, deer farmers could expose their animals to novel events prior to a brief re-exposure before transport to the abattoir. This practice has been encouraged by many including Matthews (1993) and commonly advised on internet discussion groups like the deermail group located at the University of Alberta, Canada. (http://www.afhe.ualberta.ca/deerold/deernet/deermail.html; August 1998).

Although the exposure of deer to routine handling was associated with a reduction in circulating plasma cortisol concentrations, there is no evidence to support the view that this reduced the occurrence of ecchymosis in these castrated deer.

Ecchymosis did not appear to affect meat-keeping quality of the meat up to four weeks after slaughter, using the microbiological markers used in the meat industry. The various meat quality parameters shown in table 9.4 are a useful guide for fallow deer carcasses from castrated bucks, and possibly does, but may not be useful for comparison with carcasses from bucks slaughtered during the rut, because it is known (Mulley *et. al.* 1996) that carcass composition changes significantly at that time.

10.5 Outcome

- That habituation of fallow deer to regular mustering through stockyards significantly decreased the levels of circulating cortisol and abated the degree of flightiness.
- That the keeping quality of venison affected with ecchymosis was no different to the keeping quality of unaffected meat, up to four weeks post-slaughter.

11. Recommendations to Industry

1. The thoracic stick method of exsanguination should be incorporated into all slaughter systems used for deer.

2. Attempts should be made to reduce the interval between stunning and the initiation of exsanguination.
   a) Ideally, the interval should be less than five seconds.
   b) In slaughter systems where the interval can be reduced to less than 10 seconds, captive bolt stunning rather than head only electrical stunning may be the preferred method.
   c) Where the interval cannot be reduced to less than 10 seconds, head only electrical stunning may reduce ecchymosis in comparison with captive bolt stunning. However, when using head only electrical stunning, exsanguination **must** be initiated within 20 seconds of stunning, or captive bolt stunning should be used.

3. The **minimum** voltage required for humane head only electrical stunning of fallow deer is 150 volts for a current duration of 1 second.
   a) Higher voltages may be used with no adverse affects on ecchymosis expression, and it is possible that a longer stun current duration of 3 seconds may reduce the incidence of ecchymosis in comparison with a 1 second duration.
   b) The humane head only electrical stunning of deer assumes correct placement of the electrodes transversely across the dorsal surface of the neck no more than 3cm caudal to the base line of the ears. The probes should point cranially and must pierce the skin.

4. The commercialisation of a fallow deer restraining device that limits the movement of the hind limbs to less than their maximum potential **after** rendering the animal insensible by stunning should be investigated.

5. Only the minimum number of male fallow deer required to maintain a supply of animals for slaughter throughout the breeding season should be castrated.
   a) Culling policies should aim to incorporate non-pregnant fallow deer does into the supply schedule over the breeding season.
   b) The slaughter of entire fallow deer bucks should commence as soon as possible after the peak breeding season **but only** when aggressive rutting behaviour has ceased.

6. Fallow deer venison should not be exported as whole carcasses. Carcasses should be further processed to enable the detection and condemnation of meat exhibiting ecchymosis.
   a) Where this is not possible, the left round may be inspected for the presence of ecchymosis while attached to the carcass, via the removal of the *M. tensor fasciae latae*. Where ecchymosis is detected in the left round of a carcass by this method the carcass should not be exported whole as usually ecchymosis will be exhibited in every other hind leg primal and loin.

7. When deer carcasses are further processed, venison should not be inspected until after the denvering process, as superficial ecchymosis (grade 1) is often removed with slaughter.

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Appendices

Appendix 1 Ecchymosis grading chart for deer. RIRDC project [DAS-43A] (1996)

Appendix 2 AusMeat specifications for venison.

Appendix 2 (cont'd)