Chapter one:

General Introduction

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1.1 An historical overview of the development of the Australian deer industry

1.1.2 The introduction of deer to Australia

Populations of feral deer in Australia originated from the release of some 20 species of deer by various acclimatisation societies and a few wealthy private land owners beginning in the early 1800's (Mulley, 1989; Mylrea, 1992). Of these, six species remain in feral populations including red deer (*Cervus elaphus*; spp. *elaphus*, *soticus*, *hippelaphus*), fallow deer (*Dama dama dama*), rusa deer (*Cervus timorensis*), sambar (*Cervus unicolor*), axis or chital deer (*Axis axis*), and hog deer (*Axis porcinus*) (Whitehead, 1972; Chapman and Chapman, 1975; Mylrea, 1992). While the liberation of deer occurred in all states, the eventual geographical distribution of feral deer populations appeared to have been modified (Figure 1). A number of factors may have influenced this including human habitation of bush land and the ability of the various species to adapt to the Australian environment (Mylrea, 1992).

1.1.2.1 The farming of deer: Pioneering phase

The Australian farmed deer industry began in the 1970's following closely behind the establishment of intensive deer farming systems in New Zealand where deer farming began in the late 1960's with the capture of feral deer. The initial supply of animals for the Australian deer industry came from the live capture of fallow deer from feral herds in NSW (Mulley, 1989), red deer in Queensland, and rusa deer in the Royal National Park near Sydney. Due to the comparatively large size of the feral population of fallow deer in Australia, fallow deer constituted about 70% of the farmed deer population in the early 1980's (Mulley, 1989) with the balance being mainly red deer. Although a small number of sambar and chital deer found their way on to farms during the early pioneering days (Mulley, 1989), they remained only in small numbers and were relatively insignificant economically.
Figure 1: The distribution of feral red deer, rusa deer, and fallow deer populations in Australia.

Rusa deer remained a fairly strong component of deer farming in Queensland. In general, the successful domestication of feral deer was instigated by existing land holders looking for alternatives to traditional livestock enterprises, and with prices for red and fallow deer reaching in excess of $3000 per head in the mid 1980’s they became an attractive alternative livestock enterprise that produced high returns off small areas of land and quickly paid off investment in infrastructure.

1.1.2.2 The farming of deer: Investment phase

With financial returns of over 100% per annum on investment achieved by some of the early pioneers from the buying and selling of breeding stock, interest in the farming of deer spread to people not traditionally associated with the agricultural sector. A number of investment schemes emerged to acquire the capital required to establish holding farms and stock them with deer imported from countries such as New Zealand, where at the time (1985) prices for breeding stock had begun to drop in response to supply meeting demand. From the mid 1980s up to about 1991 some 900 animals were imported into Australia annually, mainly from New Zealand (RIRDC, 1996). Live deer imports were generally confined to the larger species, red deer and North American wapiti (Cervus elaphus; spp. roosevelti, nelsoni, nanotobensis),

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although some Mesopotamian fallow deer (*Dama dama mesopotamica*) semen was also imported. The nature of the deer industry at the time could be characterised by the title of a major deer publication entitled “Gold on Four Feet” (Anderson, 1978).

1.1.3 The end of the Pioneering and Investment phases

In 1990 - 1991 the investment phase of the Australian deer industry came to an abrupt end. Within the space of 12 months prices for red deer hinds of New Zealand and/or European origin dropped from around $2500 to $800 per head. The most important aspect of the collapse in prices was the speed at which it occurred. In early 1990, 3000 red deer hinds and 40 stags of New Zealand and European origin which belonged to one NSW enterprise were sold by auction after the death of one of the company’s major shareholders. An average price of around $2400 was realised, which while being reasonable for the time was still below that suggested by those promoting the industry to new investors. The other important factor related to this auction was the number of deer offered for sale. 3000 red deer easily filled the requirements of those few people with properties well enough established to take deer. Within six months another 3000 imported red deer owned by a number of city based investors but managed by one entrepreneur, were sold by auction. These deer realised an average price of only $1800. A domino effect ensued as many investors frightened by the rapid decline in the value of their livestock left the industry. By the end of 1991 New Zealand red deer could be purchased for $800 per head, which was less than the cost of freight and quarantine.

The Australian deer industry began exporting venison in small quantities during the 1980’s, but the major focus at that time was on developing more breeding based enterprises and luring investors into the industry. This led to an inconsistent supply of stock for slaughter. The first export accredited abattoir for the slaughter of deer opened at Muswellbrook, NSW in 1989, but closed down in 1991 due to low volumes of stock available for slaughter, and variable market opportunities. The reliance of producers and processors on returns from the production of venison was also delayed for a short time when a market for live red deer was developed in Korea. In 1995-96 some 5000 red deer were exported from Australia live (RIRDC, 1996) and this helped to sustain prices for deer at levels above that commanded for venison alone.
1.1.4 The Production or Commercial phase

By 1996, estimates of the number of deer on farms in Australia ranged from somewhere between 188,000 and 230,000 deer (RIRDC, 1996; Sinclair, 1997). In 1996 the population of farmed deer in Australia was estimated to be made up of approximately 48% fallow deer and 45% red deer, with the remaining 7% being mainly rusa and chital deer (RIRDC, 1996). Accurate data on the number of each species of deer currently farmed in Australia was not available but industry estimates in 1996 suggested the growth rate of the farmed deer population to be less than 10% per annum (RIRDC, 1996). It also appeared that the proportion of red deer numbers represented on Australian deer farms had increased, compared with the other species (RIRDC, 1996). By 1996, 65% of the farmed deer population existed in NSW and Victoria and was generally confined to red or fallow deer, with the majority of rusa deer farmed in Queensland (RIRDC, 1996; Sinclair, 1997). Deer farming in Tasmania remained exclusive to fallow deer.

As the investment phase of the Australian deer industry ended and demand for breeding stock declined, those who remained in the industry established the commercial phase, which involved the sale of venison, velvet, and other by-products. Almost all of the venison vendors who operated in 1998 had been involved in the developing Australian deer industry during the 1980's or earlier. The Australian venison market throughout the investment and commercial phases was supplied by New Zealand. However, a number of new domestic markets for Australian venison were also established by deer farmers in their local areas as a means of disposing of surplus stock. Importantly, the New Zealand deer industry which dominated the world market for farmed venison, slaughtering over 400,000 deer in 1998 (New Zealand Deer Farming Annual, 1998) chose to direct their supply to markets in Europe and the USA and did not slaughter deer to Muslim requirements, which left the Muslim market in Malaysia available for Australia to exploit.

Throughout Australia there were approximately 8 venison traders supplying the export market, accounting for 85% (1000 tons) of the venison produced in Australia
annually. There were also some 20 venison traders supplying the domestic market, accounting for the remaining 15%. In 1996 approximately 34,000 deer were slaughtered (Australia Deer Farmer, 1997a, 1998a).
1.2 The Australian venison industry - The current situation

1.2.1 Factors associated with the commercialisation of the deer industry

Wood et. al., (1994) put forward four key factors associated with the successful commercial development of new industries which provide a framework to describe the commercial development of the Australian deer industry. The key factors were research and development (R&D), production, processing, and marketing.

1.2.1.1 Research and Development (R&D)

The main organisations involved in the R&D sector of the Australian deer industry were the Rural Industries Research and Development Corporation (RIRDC) who had the responsibility of administering R&D funding, the R&D advisory committee elected by the Deer Industry Association of Australia (DIAA) which was the national representative body of the Australian deer industry, and various research organisations

Figure 2: The organisational structure of the Australian deer industry Research and Development sector (After Thonard, 1998).
who put forward proposals to conduct relevant research and development activities (Figure 2) based on strategies put forward by the R&D advisory committee (Figure 3). There were generally no dedicated extension services for the Australian deer industry although some state departments of agriculture had officers working with the deer industry as well as other industries. More recently (1998) the Deer Industry Company (DIC) was established which employed a full time extension officer. The agenda of the officer included the implementation of a QA program, establishment of an industry data base, collation and dissemination of information, and numerous other tasks common to extension officer roles. The degree to which this position fulfilled the traditional role of extension was undetermined.

The RIRDC deer program manager, together with the DIAA R&D advisory committee were responsible for creating a 5 year strategic plan which prioritised a number of R&D activities seen as important to the sustainability of the Australian deer industry. The 5 year strategic plan (Figure 3) was the document upon which research organisations based their proposals for funding to conduct research activities (Thonard, 1998).

Financial support for R&D came from statutory levies imposed on venison, velvet and live exports, and government contributions based on the value of the industry’s gross annual product (Thonard, 1998). Annual funding for R&D received from levies had decreased significantly over recent years from $296,000 in 1995/96 to estimated figures of $150,000 in 1997-98 and 1998-99 (Thonard 1998).
**5 year strategic plan**

1. Increase the size of the deer population.
2. Improve slaughtering and meat processing efficiency.
3. Enhance information transfer.
4. Produce high quality deer products.
5. Develop non-chemical means of harvesting velvet.
6. Improve production efficiency by producing superior venison and velvet at lower costs and receiving higher prices at the farm gate.
7. Develop value added products.
8. Develop current markets more effectively, obtaining better returns and identifying new markets.

(Thonard, 1998)

**Key R&D issues for 1999-2000**

To improve the returns to producers and processors and expand the industry by:

- Facilitating greater coordination between venison processing operators to develop common purchasing conditions and standard carcase classifications;
- Defining the characteristics of the venison supply chain and the scope for strategic cooperative alliances;
- Developing the parameters for the possible introduction of a 'venison quality' brand for Australian production;
- Investigating and developing the predictors of the eating qualities of venison for each species;
- Objectively assessing nutritional requirements of deer, particularly those grown primarily for meat production;
- Developing a velvet marketing strategy; and
- Identifying and developing non-chemical means of harvesting velvet.

(RIRDC, 1998)

Figure 3: Australian deer industry 5 year strategic plan.

1.2.1.2 *Marketing*

One of the first major R&D initiatives undertaken by the deer industry was the development of markets for Australian venison. A full time market development consultant was employed for a number of years and their work included the standardisation of specifications for venison processing (AUSMEAT specifications), the promotion of Australian venison in overseas and domestic markets, the
development of generic promotional material, and general market research. As markets for venison were progressively established, and demand appeared to surpass supply, the focus for R&D shifted from marketing to the development of the processing and farming sectors, as was indicated in the 5 year strategic plan previously described (Figure 3).

By 1998, there were a number of venison traders operating in Australia catering for both export and domestic markets. From lists published in the Australian Deer Farming journal (Australian Deer Farmer, 1997a, 1998a), the major industry publication, there were over 20 vendors supplying the domestic market and approximately 8 supplying export markets. In 1996 it was estimated that of the 85 % of Australian venison exported, 50 % went to Europe and 50 % to the USA and Asia (RIRDC, 1996), compared with years prior to 1996 when 85 % of the venison exported was exported to the Muslim market in Asia (Tume, 1996). Although there were no accurate industry statistics to consult, contact with vendors over the course of the current study also confirmed a trend away from the supply of the Malaysian Muslim market to increasing volumes of venison going to Europe.

1.2.1.3 Production

188,000 to 230,000 deer were estimated to be farmed in Australia on approximately 1200 farms (RIRDC, 1996). While this suggested an average of approximately 175 deer per farm, in reality there were a small number of large farms, which farmed up to 6000 deer, and a large number of small farms, often with less than 50 deer. A recent survey of deer farms in Queensland for example, showed that 76.8 % of the deer farms in that state had less than 200 deer each, and 31 % had less than 50 deer. The total number of deer farmed in Queensland was estimated to be around 21,000 (Sinclair, 1997).

By 1998 the focus for R&D funding had shifted from marketing to production oriented goals, and two methods of increasing the volume of venison produced by the Australian industry were being attempted. These were, 1) to increase the number of deer farmed in Australia, and 2) to increase the volume of venison produced by the existing herd (Figure 3). From data collected by the DIC it was clear that the
production potential of the existing herd based on New Zealand standards was far from being met. In a survey of 19 Australian venison processors in April 1998, 60% of red deer carcases were less than 55 kg's, and 73% of fallow carcases were under 23 kg's (Australian Deer Farmer, 1998a). In contrast, in New Zealand red deer carcases of between 55 and 60 kg's and fallow deer carcases of 30 kg's were considered the norm as reflected in current price schedules (The Deer Farmer, 1997).

1.2.1.4 Processing

The export processing sector of the deer industry in Australia has shown little stability since the first slaughter of deer for export took place in the 1980's. As mentioned earlier the first export accredited abattoir in Australia opened in 1989, only to close in 1991 due to lack of consistent supply. After that a number of different slaughter systems emerged to cater for the processing of deer. Generally, those were divided into two categories; one being for export and the other for domestic supply. The boning and packaging of deer carcases for the domestic sector was generally carried out by the venison vendors themselves at either their own premises or those attached to the abattoirs in which the deer were slaughtered. The export sector was catered for by numerous contract boning companies servicing other livestock industries as well.

Domestic processing facilities

The slaughter of deer for the domestic market was accommodated by a number of local domestic abattoirs located in each state which also slaughtered sheep, cattle and pigs. Kills of only 10 to 30 deer a week were common, and therefore most of those facilities did not have overnight lairage for deer. In some cases the deer were shot in the transporter upon arrival at the abattoir, and were subsequently carried inside for exsanguination, skinning, and dressing. In others, exsanguination was conducted outside. Alternatively, some abattoirs had a loading ramp for deer, whereby the deer could be moved into a conventional cattle knocking box for stunning and slaughter. At all domestic abattoirs, deer were either head shot with a .22 caliber rifle or stunned using the penetrative captive bolt method (Chapter 3, page 58), and exsanguination was usually by the thoracic stick method (Chapter 3, page 54).
Export deer slaughter premises

In 1991, the first specialist deer export abattoir in Australia closed. However, by that time a number of other export abattoirs throughout Australia had begun to slaughter deer using their existing sheep and cattle chains. In those larger abattoirs fallow deer were processed on the moving sheep chain, with the larger species (red, wapiti) processed on the cattle chain. Methods of stunning and sticking varied between abattoirs and appeared to be determined by a number of factors including; the personal preferences of the abattoir staff, the knowledge and experience of the veterinary inspectors in regard to animal welfare, and the interpretation of the slaughterman of the religious requirements for the market to which the carcases were destined. In the case of Muslim slaughter the methods of stunning and exsanguination accepted by the Muslim slaughtermen varied considerably between abattoirs (Falepau, unpublished).

1.2.1.5 The instability of the processing sector

In January 1996 when the current study commenced, Victoria, Queensland and Western Australia each had one export abattoir which slaughtered deer and there were three operating in NSW, with one of those adjacent to the NSW - Victorian border. By May 1996, on the eve of attempting to put in place recording systems to monitor the prevalence of ecchymosis at abattoirs and boning rooms, the export abattoirs in Victoria and two of the abattoirs in NSW ceased slaughtering deer. Of the two remaining abattoirs in eastern Australia, the abattoir in Queensland was privately owned and access to slaughter services for other venison processors was limited.

For the remainder of 1996 and throughout 1997 very few deer were slaughtered in Australia. Only 1239 deer were slaughtered for export in NSW from the beginning of September 1997 to the end of March 1998 which was normally the peak killing season (NSW Meat Industry Authority, 1997-98). Fortunately, during that time a number of small abattoirs, primarily established to slaughter ratters for export, realised the potential to increase their throughput by slaughtering deer also. With only minor modifications required to enable the restraint of deer for stunning two such abattoirs began slaughtering deer in early 1998, one in South Australia and one in Victoria near the border between NSW and Victoria. In addition to this a small export abattoir established for the slaughter of deer only was opened in NSW in mid 1998, and soon
after one of the large multi-species abattoirs in NSW that had previously ceased slaughtering deer, resumed.

Up until 1996, deer in Tasmania were slaughtered for domestic consumption at a number of small registered on-farm slaughterhouses. However, changes to meat hygiene and safety standards in 1996 saw most of those slaughterhouses close, which left only a few conventional abattoirs to slaughter deer. Those abattoirs also ceased slaughtering deer shortly after, leaving only one abattoir which slaughtered ratites and fallow deer.
1.3 Venison Quality

As research priorities 2 (improve slaughtering and meat processing efficiency) and 4 (produce high quality deer products) suggest, the importance of venison quality to the sustainability of existing market share and/or the creation of new markets was recognised by the R&D committee in the 5 year strategic plan (Figure 3). Two projects were initiated by the R&D committee to address venison quality, one of which was the Quality Assurance program, the other the identification of factors associated with ecchymosis in deer.

1.3.1 Development of a deer industry Quality Assurance program

In 1996 the R&D committee appropriated funding for a consultant to establish an industry wide Quality Assurance (QA) program in anticipation of an increasing demand for quality assured product from export markets, particularly in the US and Europe. The deer industry QA program had 3 levels of accreditation, the first of which cost the applicant A$50 for registration, which included a “Best Practice” manual for deer farming. The scheme also extended to cover transport with another “Best Practice” manual for an additional A$50. Applicants then conducted a self assessment of their operations to obtain level three accreditation. Level two accreditation was achieved after a nominated deer industry QA assessor had inspected the operation and confirmed compliance with the “Best Practice” manuals at a further cost of A$200 for the inspection and a variable amount for reimbursement of traveling costs. QA assessors were employed on the basis of previous experience in the deer industry and as a result the positions were generally filled by existing processors and/or farmers some of whom had interests in numerous operations (Falepau, unpublished). In an attempt to ensure consistency of assessment standards all QA assessors completed their first assessment of a deer farming operation under the supervision of the DIC extension officer. Once level two accreditation was achieved compliance with the “Best Practice” manuals and the accuracy with which records were kept became the responsibility of the farmer or transporter. Level one accreditation involved initial and continued assessment by an external auditor.
accredited under the International Standards Organisation (ISO) and was thus considered the highest level of accreditation possible.

By the end of 1998, approximately 12 months after QA accreditation became available no farms had obtained level one accreditation, 9 had registered and purchased manuals (level three accreditation), and 5 of these had obtained level two accreditation. One of these farms also had level three accreditation for transport (Australian Deer Farmer, 1998b).

1.3.2 The ecchymosis project

At the same time that the deer industry QA campaign began (1996), ecchymosis particularly in fallow venison was recognized by a number of venison vendors and farmers as a major problem impacting on the quality of Australian venison and the profitability of deer farming (Mulley, 1994). In a number of instances venison vendors were reported to have deducted the projected retail value of venison exhibiting ecchymosis from payments made to farmers for the supply of live animals (Falepau, unpublished). Presumably this practice was based on the assumption that ecchymosis in deer was attributed to events in the production and processing chain that occurred prior to transportation, lairage, stunning and slaughter. Accordingly the R&D committee appropriated funds towards researching the factors associated with ecchymosis in deer, in an attempt to develop ways of minimising its occurrence. The University of Western Sydney-Hawkesbury (UWS-H) was the research organisation contracted to conduct the project upon which the current study was based, beginning in 1996 and continuing through until the end of 1998.

1.3.3 Reducing the incidence of ecchymosis

In developing the proposal put forward by UWS-H to investigate methods of reducing ecchymosis in deer, negotiations with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) initiated by UWS-H resulted in the funding by these two organisations of a concurrent project investigating factors associated with pre-slaughter stress in fallow deer with a particular focus on how it might affect the expression of ecchymosis. Working in collaboration with CSIRO enabled the current study to focus on factors associated with the slaughter systems available for deer as a
factor that could be immediately manipulated by human intervention, as opposed to
the manipulation of intrinsic physiological responses to pre-slaughter stress which
may have required relatively long term methods of intervention such as selection and
habitation.

The current study comprised a number of areas of investigation associated with
reducing the prevalence of ecchymosis in deer slaughtered in Australia, and quality
improvement in general. Attempts were made to define the extent to which
echymosis occurred in deer and associated with that activity the slaughter systems
available for deer were described (Chapter 5). For some slaughter systems the
associated prevalence of ecchymosis was determined and that informed the basis of an
experimental program investigating methods of slaughter.

The methodological approach to the current study incorporated principles of the
“Farmer first” paradigm put forward as an alternative to the traditional Transfer of
Technology (TOT) approach. This was in order to assess firstly the potential for
participatory research in the Australian deer industry, and secondly the nature of the
commercial sector with respect to the potential for the improvement of venison
quality, in particular the reduction of ecchymosis and the implementation of the QA
program. Facilitated by the methodological approach the appropriateness of both the
Transfer of Technology and “Farmer first” paradigms to the development of the
Australian deer industry were also discussed (Chapter 5).

From case studies of existing slaughter systems (Chapter 5) and a review of the
literature related to ecchymosis in a number of other domestic livestock species
(Chapter 2) the experimental approach was designed to include comparisons between
combinations of stunning and exsanguination methods and the length of the interval
between stunning and the initiation of exsanguination (Chapter 9). The head only
electrical stunning of fallow deer was investigated with respect to both ecchymosis
expression and animal welfare (Chapter 8) as the literature regarding the latter was
extremely limited and it was apparent that the welfare of animals in a number of
slaughter premises was compromised using that method.
During the course of the current study, observations from experiments where deer of different sex types were inadvertently included in groups slaughtered to investigate stunning and exsanguination methods indicated that some sex types may have been more predisposed to ecchymosis than others. This was also indicated from results which emerged from the concurrent CSIRO study and so the current study included the investigation of sex type as a predisposing factor to ecchymosis (Chapter 9).
Chapter two: Literature review

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2.1 What is ecchymosis?

There are two different haemorrhagic syndromes associated with the slaughter of animals (Petersen et. al., 1986). Blood splash, which is referred to as ecchymosis throughout this study and is associated with captive bolt and head only electrical stunning methods, and speckle, which is more frequently associated with head to body electrical stunning (Gilbert and Devine, 1982). Ecchymosis can vary in severity from the least severe cases involving only a few spots, to the worst cases where hundreds of spots may cover the entire surface of a muscle (plate 1, page 20) or be visible on the external surface of a carcase (plate 2, page 20).

Ecchymosis appears as small dark spots on the surface of various muscles of a carcase and some organs. In severe cases ecchymosis may extend deep into the muscle. The spots seen on the surface of skeletal muscles range from 1 mm to 1 cm 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 carcase, 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 carcases have shown them to be due to the localised 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 fibres (Leet et. al., 1977).
Plate 1  Severe ecchymosis in fallow venison striploin, undenvered and denvered.

Plate 2  Ecchymotic lesions visible externally on a whole fallow deer carcase.
2.2 The rupture of muscle blood vessels

In attempting to explain factors associated with ecchymosis, Thornton and Gracey (1974) put forward the following diagrammatic representation (Figure 4) and posited that ecchymotic lesions were caused by the bursting of capillaries as a result of their sudden engorgement with blood. This sudden engorgement was suggested to be caused by the vaso-dilatation of arterioles, immediately after vaso-constriction stimulated by muscular contractions associated with electrical stunning. Gregory (1987) maintained this thesis adding that the rupture of blood vessels was more likely to occur if aneurysms caused by the super-contraction of muscle fibres occurred simultaneously with an increase in systolic pressure.

![Diagram of arteriole, venule, capillary showing vaso-constriction and vaso-dilatation](image)

(Thornton & Gracey, 1974)

Figure 4: Engorgement and rupture of capillaries.

While the diagram of Thornton and Gracey (1974) (Figure 4) depicted blood vessel rupture occurring in the capillary bed, it was also shown histologically that ruptures associated with ecchymosis occurred in larger blood vessels too (Shaw et. al., 1971; Leet et. al., 1977), and most of the literature has referred simply to the ‘rupture of blood vessels’.
2.3 The stunning of livestock

Historically the occurrence of ecchymosis was associated with the introduction of stunning prior to exsanguination (Tweed et. al., 1931; Anthony, 1951), particularly those methods of stunning which did not cause immediate cardiac arrest including; penetrative captive bolt stunning, percussion stunning, and head-only electrical stunning (Kirton et. al., 1980-81a). Up until the 1930's, stunning was generally only used prior to exsanguination where deemed necessary to immobilise large animals to make easier subsequent exsanguination (Anthony, 1951). Eventually however, as concerns over the humane killing of livestock arose, countries progressively began implementing pre-slaughter stunning in order to render the animal insensible to pain until death supervened from loss of blood.

A number of methods of stunning were developed over the years, the first of which involved inducing a state of concussion simply by striking the animal on the head with a pole axe similar to a large hammer but with the head having a blunt end which did not penetrate the skull, or a pointed end which did. The pole axe was subsequently replaced by a range of mechanical stunners, of which there were three types, operated by explosives, compressed air, or hydraulics, including the penetrating captive bolt (plate 3, page 23), the non-penetrating captive bolt, and the use of a firearm. Much like the pole axe, the heads of most captive bolt stunners could be changed to either comprise a rod which fired into the skull of the animal, or a dome shaped head which did not (Grandin, 1983).

Electrical stunning, which involved the passing of an electrical current through the animals brain was the next development in pre-slaughter stunning. Two types of electrical stunning were developed; head only stunning which involved the passing of an electrical current through the brain only (plate 4, page 23), and head to body, which involved the passing of a current from the head through to either the back, or the foreleg. The main difference between the two methods was that animals could recover from head only electrical stunning should their throat not be cut, whereas
Plate 3  Penetrative captive bolt stunning of fallow deer in a v-drop floor crush.

Plate 4  Head only electrical stunning of fallow deer showing correct placement of the electrodes within 3 cm caudal to the base of the ears and pointing cranially.
with head to body stunning, as the current passed through the heart and caused cardiac arrest, the animal would not recover (Gilbert, 1993).

Carbon dioxide (CO₂) stunning which involved containing the animal in a chamber filled with CO₂ for a period of time prior to exsanguination was first developed in the 1950's, and was generally only used for the stunning of pigs due to the high capital cost of the equipment and loss of gas in the coat or fleece of other animals (Blackmore, 1979). There was also a continuing debate regarding whether CO₂ stunning itself was distressing to the animal (Grandin, 1983).

The purpose of stunning is to render an animal unconscious prior to subsequent exsanguination and a number of visual indicators can be observed when a successful stun is induced. As a result of a successful captive bolt stun the animal collapses immediately, and muscle contractions which cause the curling of the tail or tensing of the neck should last for approximately 3 to 5 seconds (Grandin, 1983). The ears should also droop and become completely relaxed after 3 to 5 seconds (Grandin, 1983). 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 arching of the neck and backward movement of the head, and the cessation of respiration (plate 5, page 25).
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 (plate 6, page 25). In contrast, in captive bolt stunned deer this phase usually commences within 5 seconds.
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).
Plate 5  A fallow deer exhibiting a tonic phase reaction 5 seconds after being stunned using the head only electrical stunning method (extended fore limbs, arched neck, and hind legs flexed cranially).

Plate 6  A fallow deer exhibiting a clonic phase reaction 5 seconds after being stunned using a penetrative captive bolt stunner (paddling movement of the hind and fore legs).
As mentioned earlier, the occurrence of ecchymosis was associated initially with the shooting or stunning of animals prior to exsanguination (Tweed, et. al., 1931; Anthony, 1932, 1951) and a number of explanations were put forward to explain the phenomena. Woodridge (1922) and Parker (1929), cited by Tweed et. al. (1931), associated the delay between stunning and exsanguination with ecchymosis, and Dunkin and Hill (1924), also cited by Tweed et. al. (1931), put forward violent muscular contractions as the cause. Tweed et. al. (1931) themselves, chose to investigate blood pressure changes resulting from the stun as a possible explanation behind this phenomena. Tweed et. al. (1931) measured arterial and venous blood pressure changes in sheep, as they were deemed a workable laboratory model, before, during and after captive bolt stunning and their recordings are shown in Figure 5 below.

![Blood pressure graph](Tweed et. al., 1931)

Figure 5: Blood pressure changes caused by captive bolt stunning. Arrows indicate point of shooting.

In sheep, arterial blood pressure rose immediately upon captive bolt stunning and within 5 seconds had at least doubled (Figure 5). Simultaneously, heart rate increased and respiration ceased either immediately or after a few gasps, returning again after varied intervals (Tweed et. al., 1931). Venous pressure increased when respiration stopped (Tweed et. al., 1931). Importantly with respect to ecchymosis, Tweed et. al. (1931) did not find the elevation of blood pressure to be associated with the occurrence of ecchymosis in his trials, which confirmed that there were other factors involved.
As alternative methods of stunning were developed and different incidences of ecchymosis were seen to be associated with those methods, blood pressure changes were again investigated. Clark and Tweed (1932) measured blood pressure changes associated with electrical stunning, and Kirton et. al. (1978) compared blood pressure changes associated with electrical and captive bolt stunning. Both methods were shown to cause a similar pattern of blood pressure changes. Kirton et. al. (1980-81b) later showed electrical stunning to be associated with a higher incidence of ecchymosis than captive bolt and percussion stunning, and considering that blood pressure changes had already been shown to be similar with all these methods, Kirton et. al. (1980-81b) suggested that the electrical stun itself, rather than blood pressure elevations alone, predisposed blood vessels to rupture and leak.

![Graph showing blood pressure changes](image)

*(Gilbert & Devine, 1982)*

Figure 6: Blood pressure changes caused by head only electrical stunning.

With the development and implementation of head to back stunning, which was shown to decrease the incidence of ecchymosis in lambs in comparison to head only electrical stunning (Kirton et. al., 1980-81a), blood pressure changes associated with stunning were investigated again. Gilbert and Devine (1982) and Petersen et. al. (1986) both investigated blood pressure changes associated with head only and head to back electrical stunning and showed marked differences between the two methods. Head only stunning caused a two to three fold increase in arterial pressure and fluctuating increases in venous pressure (Figure 6), in contrast with head to back
stunning which caused a decrease in arterial pressure and a more steady elevation of venous pressure (Figure 7).

![Graph of blood pressure changes caused by head to back electrical stunning.](image)

(Gilbert & Devine, 1982)

Figure 7: Blood pressure changes caused by head to back electrical stunning.

While head to body electrical stunning provided a way of minimising ecchymosis, a number of other factors influenced both the implementation of stunning prior to slaughter throughout the world, and the means by which the animals were stunned. Religious slaughter including kosher or Muslim slaughter, demanded a number of fundamental rules be followed including:

- the animal being healthy prior to slaughter,
- the animal bleeding to death from a throat cut inflicted by a specially trained slaughterman, and
- the heart beating until the animal had died from loss of blood.

Initially, all ritual slaughter, and some non-ritual slaughter was performed without prior stunning. However, over time, concerns regarding the humanness of the slaughter process deemed that in many countries by law, stunning was included in the process. In some parts of the world, such as the United Kingdom where ritual slaughter was not a significant concern, stunning prior to slaughter was made mandatory as early as 1933 (Wotton et. al., 1992). In other countries such as Australia
and New Zealand where adherence to ritual slaughter requirements was important to satisfying particular markets, stunning prior to exsanguination was not made compulsory until the 1970's. With ritual slaughter, the requirement that animals bleed to death as a result of the throat cut inflicted by the slaughterman precluded the use of some methods of stunning including; head to body electrical and CO₂ stunning which stopped the heart prior to exsanguination, and penetrative bolt stunning which was irreversible and thereby implied that the stunner killed the animal rather than the Muslim slaughterman.

In ritual and non-ritual slaughter systems, the implementation of stunning prior to exsanguination was also influenced by the speed at which the rest of the slaughter system could operate, and the type of restraint used to present the animal for the application of the different types of stunners. By the time compulsory stunning was introduced in Australia and New Zealand, conveyer systems capable of presenting over 500 animals an hour to the slaughterman were in operation for the slaughter of sheep and goats. Electrical stunning was commonly used as it was cheap, quick, and the head only method in particular was accepted by the appropriate religious authorities for ritual slaughter. With the conveyer systems the animals were restrained sufficiently to apply the electrodes of an electrical stunner for the required duration, as opposed to non-conveyer systems such as those commonly used for cattle. In Australia, the slaughter of fallow deer was for some time accommodated using sheep slaughter systems at a number of large multi-species abattoirs. Red deer were slaughtered using systems designed for cattle which did not comprise conveyer restraint systems and operated at a slower speed. In New Zealand, the slaughter of deer was accommodated by ‘Deer Slaughter Premises’ (DSP’s), which only slaughtered deer, and were more similar to cattle slaughter systems than to the aforementioned sheep systems.
2.4 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 and Newhook, 1976) for non-ritual slaughter, were 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 so the thoracic stick method of exsanguination became the common method used for the slaughter of pigs.
2.5 Research on ecchymosis

From the available literature it was apparent that a number of factors affected 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 differed considerably between the slaughter systems employed for the various species of livestock concerned. Research on ecchymosis, some of which was 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 have been reviewed separately.

2.5.1 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. Charles (1960) reported observations made over six years 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;
• increases in blood pressure,
• muscular contractions at the time when blood pressure was raised, and
• delays in the 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 carcases, but very seldom in the carcases 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 carcase.

Perhaps because of the low prevalence of ecchymosis in cattle carcases little research on ecchymosis in cattle has since been conducted. Daly and Simmons (1994) 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 for cattle, which was associated with a high incidence of ecchymosis in sheep (Kirton et. al., 1980-81b), in large abattoirs with slaughter systems comprising head restraint devices (see Grandin, 1983), there appeared to be no resurgence of research into ecchymosis in cattle. After 1960, apart from work reported by Smulders et. al. (1989) and Daly and Simmons (1994), 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 (Warrington, 1974; Grandin, 1983; Gilbert, 1993).

2.5.2 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 mechanised 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 pigs could therefore be stunned by any method, including those which cause cardiac arrest. In addition, they 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 the prevalence 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. Lamboooy and 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 with stunning at 70 volts for 10 seconds, transport prior to slaughter with no transport prior to slaughter, free standing at stunning with restraint in a v-restrainer, and chemical with 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 slaughter methods, comparing captive bolt with electrical stunning, and the interval between either of these methods and exsanguination, on ecchymosis in barrows (castrates) and gilts (females). There was no relationship observed between sex type and ecchymosis. Captive bolt stunning coupled with delayed exsanguination caused more ecchymosis than electrical or captive bolt stunning coupled with a short interval between stunning and exsanguination, or electrical stunning coupled with delayed exsanguination. The intervals between stunning and exsanguination varied between experiments, with one comparing 18 seconds with 144 seconds, and another comparing 9 seconds with 100 seconds. Bloomquist (1958) and van de Wal (1978), cited in Burson et. al. (1983), had previously shown that delayed exsanguination was associated with ecchymosis in both electrically and captive bolt stunned pigs, however, lower stunning voltages were used than by Burson et. al. (1983). Burson et. al. (1983) also extended the studies by Bloomquist (1958) and van de Wal (1978), cited in Burson et. al. (1983), by looking at the anatomical distribution of ecchymosis in pigs. They found that the severity of the ecchymosis exhibited, and its distribution throughout the carcasse, were similar in both electrically and captive bolt stunned pigs exsanguinated within the shorter period. In contrast, the pigs stunned by the captive bolt method and exsanguinated after the delayed interval exhibited a greater incidence of ecchymosis in the rump (M. gluteus medius) than did pigs from the other treatment groups. Burson et. al. (1983) also determined the diaphragm to be a good indicator of the presence of ecchymosis in other skeletal muscles of the pig carcasse.

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 with 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. The same authors 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 with head to back electrical stunning of pigs and found no association between the location of the electrode placement and the incidence of ecchymosis. Daly and Simmons (1994) showed that high frequency stunning of pigs reduced muscular contractions and as a result caused less ecchymosis than conventional 50 Hz stunning.

2.5.3 Sheep

Most of the work investigating ecchymosis in sheep appears to have been conducted in New Zealand when ecchymosis in the carcases 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 carcases 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, discussed in previous sections, 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.

The effect of stunning method on ecchymosis in lambs has been investigated and the least incidence was found to be associated with captive bolt or percussion stunning in comparison with head only or high frequency (130 V, 1500 Hz) electrical stunning (Clark and 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 and 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 methods, as determined experimentally, 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. Gilbert and Devine (1982) and Petersen et. al. (1986) 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, contrasting with head to back stunning which caused a decrease in arterial pressure and a more than moderate and constant increase in venous blood pressure (Figure 6). In relation to this Petersen et. al. (1986) also measured muscular activity using electromyography 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 and 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 and 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, compared 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 and Frazerhurst, 1983). Overall however, the incidence and severity was not as great as that sometimes seen in seemingly normal slaughter lines (Kirton and 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 ecchymosis in lambs and the interval between stunning and exsanguination, by comparing carcasses from lambs exsanguinated before electrical stunning, immediately after stunning, and 5 to 8 seconds after stunning, and found that the incidence of ecchymosis went from least to most respectively. This result was consistent with those regarding the effect of the interval between stunning and exsanguination in pigs (Burson et. al., 1983). These results, coupled with earlier observations in sheep that stunning caused 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 pre-slaughter stress in lambs was investigated by Pearson et. al. (1977) in an attempt to explain the different incidences of ecchymosis seen between
seemingly similar mobs of lambs, stunned and exsanguinated in exactly the same way, but on different days or at different abattoirs. The same authors measured circulating cortisol, adrenaline and noradrenalin levels in stunned and non-stunned lambs at different slaughterhouses. Cortisol levels, which were known not to be affected by the stunning procedure itself and were therefore considered by some to be a reliable indicator of pre-stun stress levels when samples were collected at exsanguination (Shaw and 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 noradrenalin 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 acquired 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.

2.5.4 Rats

In response to economic constraints on investigating ecchymosis in domestic meat animals, Shaw et. al. (1971) produced ecchymosis in laboratory rats (Rattus norvegicus) by head only electrically stunning them using 110 volts for a duration of 5 seconds. Each rat was stunned three times with each stun being 3 seconds apart. Shaw et. al. (1971) was then able to further increase the incidence of ecchymosis in rats by chemically stimulating vaso-dilatation of blood vessels, as opposed to vaso-constriction, prior to stunning. Histological examinations were carried out and the ecchymotic lesions exhibited were similar to those observed in beef.

The muscles examined by Shaw et. al. (1971) were the M. gluteus maximus and the M. vastus lateralis, which were exposed on the whole carcase by dissecting away the M. tensor fasciae latae. The extent of the haemorrhages was significantly greater in
the *M. vastus lateralis* than in the other muscles examined. Shaw *et. al.* (1971) also showed the extent of the ecchymosis to be greater in heavier rats.
2.6 *Ecchymosis in deer*

The prevalence of ecchymosis in deer, as in other species, first became a problem upon the commercialisation of deer farming, and the subsequent slaughter of deer through commercial abattoirs. As put forward in Chapter 1, incidences of ecchymosis in fallow deer in particular, have been reported by people from 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). 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 which compared 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-restraining conveyer. 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) observed a significantly higher incidence of ecchymosis in the loins of the electrically stunned fallow deer, compared with captive bolt stunned
deer. This result was consistent with results in other species as reported earlier (Clark and 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, compared with far more than this harvested each year in Germany alone, usually by shooting in a paddock or on managed estates. Far greater numbers of red deer than fallow deer are slaughtered each year in New Zealand, the former of which when compared with fallow deer, appeared to be particularly less susceptible to ecchymosis (Chapter 5, page 140).

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, 1989; CSIRO, 1995);

- reduce pre-slaughter excitement and stress,
- rest animals prior to slaughter,
- avoid double stunning,
- reduce time between stunning and sticking, and
- ‘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 Australian deer industry in order to clarify options available to reduce the prevalence of ecchymosis in fallow deer.
## Chapter three:

### General materials and methods

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3.1 Ecchymosis grading

The examination of carcases for ecchymosis in all experiments and case studies reported in the current 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 carcase or chiller grading, which involved examination of the left round while attached to the carcase,
- the commercial breakdown of carcases in a boning room, referred to as the boning room grading method, and
- complete dissection.

The chiller grading technique was developed to enable the rapid grading of large numbers of carcases at abattoirs. The technique involved the removal of the lateral apex of the M. tensor fasciae latae to expose the lateral surface of the round, more specifically the M. vastus lateralis. The muscle surface visible was then scored for ecchymosis. While only the left round ecchymosis score was recorded in this way for case study data collection, in more controlled experiments the M. cutaneous 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 carcase muscles was included in the current study (Chapter 4, page 75).

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 carcase. Using this method, ecchymosis scores were recorded for the external surfaces of the muscles which were visible for each of the particular commercial cuts or regions of the carcase. These included the loin prior to denvering (plate 1, page 20), the hind leg portions, the shoulder, and the muscles of the internal body cavity. Plates 8 to 17 show the muscle surfaces visible and/or inspected in the hind leg (plate 7, page 46), shoulder, and body cavity including:

- the internal and external surfaces of the rump (plates 8 and 9, page 46),
- the round after removal from the hind leg (plate 10, page 47), and complete removal of the M. tensor fasciae latae (plate 11, page 47),
- the internal and external muscle surfaces of the topside (M. adductor femoris, M. semimembranosus) and silverside (M. semitendinosus, M. biceps femoris) (plates 12 and 13, page 48) after removal from the hind leg (plate 14, page 48),
- the M. supraspinatus situated in the shoulder (plate 15, and plate 16 removed from the shoulder, page 49), and
- the muscles visible in the body cavity including the tenderloins (M. psoas major), internal and external abdominal muscles, and the diaphragm (plate 17, page 50).

The complete dissection of carcases in the current study to determine the distribution of ecchymotic lesions (Chapter 4, page 69) was performed using the method described by Butterfield and May (1966).
Plate 7  Whole fallow deer hind leg.

Plate 8  External surface of the rump (left) detached from the hind leg.

Plate 9  Internal surface of the rump (left) detached from the hind leg.
Plate 10  Detachment of the round from the hind leg.

Plate 11  Removal of the *M. tensor fasciae latae* from the round.
Plate 12  Internal surface of the silverside (left) and topside (right).

Plate 13  External surface of the topside (left) and silverside (right).

Plate 14  Detachment of the topside and silverside from the hind leg.
Plate 15  Fallow deer venison shoulder.

Plate 16  *M. supraspinatus* detached from the shoulder.
Plate 17  Externally visible muscles of the body cavity including the diaphragm (obscured from view), abdominal muscles (detached from caudal ends and hanging over the sides), and tenderloins (detached and held in view).
3.2 Statistical analysis

All statistical analyses in the current study were performed using either Genstat 5, 4.1 (1997), Minitab 12.1 (1995), or Minitab Student Edition 9 (1995).

3.3 Body weight

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 hot carcase weight (HCW) basis after slaughter. In order not to subject deer used in the current study to stress uncommon to commercial slaughter systems, in trials where liveweight was not likely to vary considerably between deer based on visual assessment, or where liveweight 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 liveweight was not recorded or included as a factor in the analysis of the data, the mean HCW 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.

3.4 Ultimate pH

Ultimate pH of the *M longissimus dorsi* was measured after approximately 20 hours using a standard pH meter which compensated for temperature (TPS LC80-A, Jenkins, Queensland, Australia).
3.5 **Blood sampling**

3.5.1 **Blood plasma sample collection and analysis**

Blood was collected from live deer by jugular venepuncture while blindfolded and restrained in a v-drop floor crush, or during exsanguination at slaughter. In both cases blood was collected into lithium heparinised 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.

3.5.1.1 *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-pregnene-11β, 17, 21 - triol - 3, 20 - dione 3 - CMO :BSA. Cross reactivities were, 11- deoxycortisol 8.0%, cortisolone 40.5%, 6β hydroxy cortisolone 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, 1 ml 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.

3.5.1.2 *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, oestriadiol-17β, cortisol, 20β-hydroxyprogesterone, 20α-hydroxyprogesterone, 17α-hydroxyprogesterone, pregnenolone, epitestosterone, androstenediol, androsterone,
androstenedione, 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, 1 ml 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.

3.5.1.3 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, oestriol, 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, 1 ml of buffer containing 8%W/V polyethylene glycol 6000 was added. Dilutions of a high testosterone plasma were parallel to the standard curve.
3.6 Exsanguination methods

The two methods of exsanguination (Figure 8) used in the current study, referred to as the thoracic stick and gash cut methods, were previously described by Blackmore and 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 and Newhook, 1976).

The gash cut 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 occipital-atlantal junction” (Blackmore and Newhook, 1976).

Figure 8: Gash cut and thoracic stick exsanguination methods.
3.7 Restraint devices

During the current study, four types of restraint were used commercially for the slaughter of deer.

The v-restraining conveyer (plate 18, page 56) originally designed for the slaughter of sheep and goats, was capable of presenting approximately 500 fallow deer an hour for stunning and exsanguination. In the current study, this restraint system was used in type B abattoirs described in Chapter 5 (page 132).

The squeeze crush (plate 19, page 56) comprised two padded walls which moved inwards to squeeze and restrain the deer, leaving its head protruding over the top. This restraint device was used in type D abattoirs (Chapter 5, page 137) for both red deer and fallow deer.

In type E and some type A abattoirs, (Chapter 5, page 141 and page 129), a knocking box of dimensions sufficient to restrict the movement of a deer the size of a fallow deer was used. In type A abattoirs, access for head shooting the fallow deer with a .22 calibre rifle was via a small trap door situated above the animals head. In type E abattoirs, a hole in the front door of the knocking box allowed the head of the deer to protrude for placement of the captive bolt stunner (plate 20, page 57).

In Australia, type C (Chapter 5, page 135), type B, and some type A abattoirs used a conventional cattle knocking box for red deer and rusa deer, but not fallow deer. However, in New Zealand fallow deer and red deer were observed being stunned in such a device (plate 21, page 57).
Plate 18  Type B abattoir v-restraining conveyer. The stunner operator was using a head only electrical stunner. After stunning, the deer was ejected from the restraining conveyer onto the bleeding table, where it was subsequently gash cut by the Muslim slaughterman. While it was being exsanguinated, the deer was held by the hind legs by the shackler, and then lifted to hang from the dressing out rail overhead.

Plate 19  Squeeze crush used in type D abattoirs to restrain deer, with head protruding for stunning (left). After stunning, the sides of the crush moved apart (A & B), the far side (B) lifted, and the deer was dragged out onto the slaughter floor for hoisting and exsanguination (right).
Plate 20  A type E abattoir fully enclosed ramp and knocking box for fallow deer (left). The deer remained free standing with its head protruding through a hole in the front door to enable stunning (right). The front door was swung open after stunning, the deer was dragged out onto a platform, shackled and hung from the dressing out rail, and exsanguinated by thoracic stick method within approximately 8 seconds.

Plate 21  A conventional cattle knocking box in which red deer and rusa deer were stunned at type C, and some type A abattoirs. Essentially just a small pen. The wall over which the stunner operator was leaning, lifted after stunning to allow removal of the deer, and the deer was then hoisted as in type D abattoirs (plate 19, page 56).
3.8 Stunning

3.8.1 Head-only electrical stunning

All of the electrical stunning conducted in the current study only involved the head only method using a voltage-controlled device (see chapter 8, page 179). 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 (plate 4, page 23). 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.

3.8.2 Captive bolt stunning

A penetrative captive bolt stunner (plate 3, page 23) was used with a No. 13 (yellow) charge, commonly used for sheep, pigs, horses and light cattle (Scherner & Co., Ettlingen, Germany). The bolt was applied in either the poll or frontal position (Figure 9).

![Poll position and Frontal positions](image)

Figure 9: Penetrative captive bolt stunner positions.
3.9 UWS-H abattoir and deer research farm

Due to difficulties in attempting to conduct experiments in commercial abattoirs (Chapter 5, page 112), the UWS-H abattoir was adapted to slaughter deer and licensed to supply the Australian domestic market (Figure 10). The abattoir comprised a large outside yard with two metre high walls into which the deer were received after being moved from the UWS-H deer 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 in which the deer were stunned. The deer were goaded up the ramp one at a time by closing a large door around behind the group. With the drop floor crush, the deer entered through a rear door, a side was moved in to wedge the deer between the two sides, and the floor removed (plates 22 and 23, page 60). The front door had a hole in it to allow the head of the deer to protrude for placement of the stunning device (plates 3 and 4, page 23). After the deer was stunned the front door folded down to allow the deer to be ejected.

![Diagram of UWS-H abattoir and holding yards]

Figure 10: UWS-H abattoir and holding yards.
Plate 22 UWS-H abattoir v-drop floor crush. The deer were goaded up a ramp from the dark room behind, and entered the crush through a door at the rear.

Plate 23 UWS-H abattoir v-drop floor crush with floor dropped down, side closed in, rear door closed, and front doors open.
The UWS-H abattoir was located adjacent to the UWS-H deer research farm (Figure 11), with the length of the laneway along which the deer were moved between the deer farm handling shed and the abattoir being approximately 180 metres. The deer farm comprised approximately 10 hectares, divided by a road running north to south. 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 UWS-H 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.

Figure 11: UWS-H abattoir and deer farm showing route the deer traveled from the farm handling shed to the abattoir.
Chapter four:

Anatomical distribution of ecchymosis

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4.1 Introduction

The current 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) is 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 carcase 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 post mortem inspection of the visceral organs after removal,
3. an inspection of the whole carcase prior to storage, involving muscles visible within the thoracic and abdominal cavities and the external surfaces of the carcase, and
4. where carcases 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 carcase inspection on the slaughter floor at the abattoir. From the abattoir, some carcases 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 (plate 1, page 20). Often the denvering process also removed almost all visible ecchymotic lesions.

During the current study (1996-1998) a significant number of whole carcases, as opposed to packaged commercial cuts, were being exported from Australia (Falepau, unpublished). The inspection of these carcases for ecchymosis was limited to the whole carcase inspection carried out on the slaughter floor at the abattoir. In previous studies with sheep where only the whole carcase was inspected by visual examination of external surfaces (Kirton and Woods, 1976) muscles affected by ecchymosis that were not visible externally were missed. Anecdotal reports from boning rooms where deer carcases 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 carcases exported from Australia as undesirable, some venison processors refrained from boning carcases 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 carcases were affected by ecchymosis would enable processors to withhold carcases 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 carcases 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 carcase 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 carcases 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 carcase or commercial cuts into which carcases 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 and Frazerhurst, 1983; Lambooy and 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 carcase 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 and Frazerhurst, 1983) determined ecchymosis incidence on a whole carcase basis using a grading system developed by the Meat Industry Research Institute of New Zealand (MIRINZ). This 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 and 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 and Woods (1976) went further in one study to determine the extent of ecchymosis throughout the carcase by slicing whole carcases from end to end at 1 cm intervals and counting ecchymotic lesions. Ecchymosis was shown to be equally distributed between left and right sides of the carcase and the worst affected regions of the carcase were said to be the diaphragm, the flap, and areas of the ribs and loin away from the midline (backbone). In severely affected carcases, ecchymosis was found in the eye muscle, the fillet, leg and shoulder (Kirton and 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 compared 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 and 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 carcases were broken down appeared to be most alike between deer and cattle, using the AUSMEAT specifications for deer (Appendix 2) and the specifications for beef described by Butterfield and May (1966) for comparison. Accordingly, studies concerning ecchymosis in cattle (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 carcases 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 M. 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; cited in Smulders, 1989). 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 carcase.

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 throughout the current study to indicate the severity of ecchymosis in any muscles of the carcase.

During the current 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 carcases 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 carcases 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 carcase, no studies of sufficient detail had been conducted to support this.

In the current 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.

With 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 carcase could be inspected, a better understanding of the distribution of ecchymosis throughout the carcase was also a prerequisite to comparing results or considering the commercial significance of research findings.
4.2 The anatomical distribution of ecchymosis throughout the skeletal muscles of the fallow deer carcase

4.2.1 Introduction

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 carcases 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 carcase 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 carcases in order to identify the particular muscles most frequently affected by ecchymosis.

4.2.2 Materials and methods

4.2.2.1 Data source

Fallow deer carcases affected with ecchymosis were retrieved from 4 trials conducted at the UWS-H 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 (Chapter 8, page 188).

4.2.2.2 Dissection method

Venison carcases \( n=8 \) 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 and 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 ecchymosis grading chart (Appendix 1).

4.2.2.3 Statistical analysis

No statistical analysis of the data was required.

4.2.3 Results

A comparison of the hindquarter (Table 1) and forequarter (Table 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 hindquarter muscles, the *M. longissimus dorsi* and *M. vastus lateralis* were affected in all 16 of the carcase 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 carcase sides. The *M. adductor femoris* and *M. vastus medialis* were affected in 10 sides, and the *M. semitendinosus* and *M. obliquus internus abdominis* in 9. The *M. vastus intermedius* was affected in 8 carcase sides. Of the 36 remaining muscles of the hindquarter, 27 of them were affected in at least 1 of the sides inspected, but in no more than 7 of the sides.
Table 1: Ecchymosis scores for muscles dissected from the hindquarters of fallow deer carcases.

<table>
<thead>
<tr>
<th>Name of muscle (Listed in order of dissection)</th>
<th>Ecchymosis scores (Each consecutive pair of columns represents the left and right side of the same carcase. Blank squares indicate a score of 0)</th>
<th>Number of muscles affected (Number of carcases affected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M. tensor fasciae latae</td>
<td>1 2 1 1 3 3 1 3 1 1 3 3 1 3 1</td>
<td>1 (1)</td>
</tr>
<tr>
<td>M. biceps femoris</td>
<td>2 2 2 1 1 3 3 1 3 1 1 3 3 1 3 1</td>
<td>13 (8)</td>
</tr>
<tr>
<td>M. gluteus medius</td>
<td>3 3 3 2 2 1 2 2 4 3 3 1 3 4 3 3 1</td>
<td>14 (7)</td>
</tr>
<tr>
<td>M. vastus lateralis</td>
<td>1 1 2 1 2 1 3 3 2 1 1 2 2 4 3 2</td>
<td>16 (8)</td>
</tr>
<tr>
<td>M. glutus accessorius</td>
<td>1 2 2 3 1 1 1</td>
<td>6 (4)</td>
</tr>
<tr>
<td>M. glutus profundus</td>
<td>1 1 1 2 1 1 1 6 (4)</td>
<td></td>
</tr>
<tr>
<td>M. rectus femoris</td>
<td>1 3 1 1 1 1 1 1 1 2 3</td>
<td>13 (7)</td>
</tr>
<tr>
<td>M. semitendinosus</td>
<td>1 3 1 1 1 1 1 4</td>
<td>9 (5)</td>
</tr>
<tr>
<td>M. gracilis</td>
<td>1 1 1 3 2 4 (3)</td>
<td></td>
</tr>
<tr>
<td>M. semimembranosus</td>
<td>1 1 2 2 1 1 2 1 3 4 1 2 1</td>
<td>15 (8)</td>
</tr>
<tr>
<td>M. adductor femoris</td>
<td>1 1 1 1 1 1 1 2 1 1</td>
<td>10 (7)</td>
</tr>
<tr>
<td>M. gastrocnemius et m. soleus</td>
<td>1 1 2 1 1 2 2</td>
<td>7 (5)</td>
</tr>
<tr>
<td>M. flexor digitorum superficialis (s. plantaris)</td>
<td>1 1</td>
<td>2 (1)</td>
</tr>
<tr>
<td>M. pectineus</td>
<td>2 1 1 1 3 1</td>
<td>5 (5)</td>
</tr>
<tr>
<td>M. sartorius</td>
<td>1</td>
<td>1 (1)</td>
</tr>
<tr>
<td>M. gemellus</td>
<td>1</td>
<td>1 (1)</td>
</tr>
<tr>
<td>M. quadratus femoris</td>
<td>1</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Mm. obturatorii externus et internus</td>
<td>1 1 1</td>
<td>3 (3)</td>
</tr>
<tr>
<td>M. vastus medialis</td>
<td>1 4 1 4 4 1 2</td>
<td>8 (4)</td>
</tr>
<tr>
<td>M. vastus intermedius</td>
<td>1 1 1 4 4 1 3 1 2</td>
<td>10 (5)</td>
</tr>
<tr>
<td>M. articularis genu</td>
<td>- - - - - - - - - - - - - - - -</td>
<td>-</td>
</tr>
<tr>
<td>Extensor group**</td>
<td>4 1</td>
<td>2 (1)</td>
</tr>
<tr>
<td>M. peronaeus longus</td>
<td>1 1</td>
<td>2 (2)</td>
</tr>
<tr>
<td>M. extensor digiti quarti propius (pedis)</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>M. tibialis anterior</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>M. tibia posterior**</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>M. flexor digitorum longus (pedis)**</td>
<td>2 2 1</td>
<td>3 (2)</td>
</tr>
<tr>
<td>M. flexor hallucis longus**</td>
<td>2 2 1</td>
<td>4 (3)</td>
</tr>
<tr>
<td>M. popliteus</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>M. psoas minor</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>M. psoas major</td>
<td>1 1 1</td>
<td>3 (3)</td>
</tr>
<tr>
<td>M. quadratus lumbarorum</td>
<td>1</td>
<td>1 (1)</td>
</tr>
<tr>
<td>M. iliacus</td>
<td>1</td>
<td>1 (1)</td>
</tr>
<tr>
<td>M. latissimus dorsi</td>
<td>2</td>
<td>1 (1)</td>
</tr>
<tr>
<td>M. trapezius thoracis</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>M. serratus dorsalis caudalis</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>M. iliocostalis (s. longissimus costarum)</td>
<td>1 1 1</td>
<td>3 (2)</td>
</tr>
<tr>
<td>M. longissimus dorsi</td>
<td>1 1 2 3 1 1 2 2 2</td>
<td>16 (8)</td>
</tr>
<tr>
<td>M. spinalis dorsi</td>
<td>1 1 1</td>
<td>3 (2)</td>
</tr>
<tr>
<td>Mm. multifidi dorsi</td>
<td>2 3 2 3 1</td>
<td>5 (3)</td>
</tr>
<tr>
<td>M. obliquus externus abdominis</td>
<td>1 3 1 1</td>
<td>4 (2)</td>
</tr>
<tr>
<td>M. retractor costae</td>
<td>1 1</td>
<td>2 (2)</td>
</tr>
<tr>
<td>M. obliquus internus abdominis</td>
<td>3 2 1 2 3 2 2 3 3</td>
<td>9 (5)</td>
</tr>
<tr>
<td>Muscle Name</td>
<td>Score 1</td>
<td>Score 2</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>M. transversus abdominis</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>M. rectus abdominis</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mm. sacroccocygeal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. levator ani (s. retractor ani)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mm. intercostales externi et interni</td>
<td>1 1</td>
<td>1</td>
</tr>
<tr>
<td>Mm. levatores costarum</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M. coccygeus</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mm. intertransversari caudae</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M. ischiocavernosus</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M. praeputialis caudalis</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M. praeputialis cranialis</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(s. protractor praeputii)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
* equal to zero.
- not scored because muscle was either too small for inspection or only a small fragment remained on the dressed carcase.
** Extensor group muscles comprise; M. peroneus 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.

---

**Table 2: Ecchymosis scores for muscles dissected from the forequarters of fallow deer carcases.**

<table>
<thead>
<tr>
<th>Name of muscle (Listed in order of dissection)</th>
<th>Ecchymosis scores (Each consecutive pair of columns represents the left and right side of the same carcase. Blank squares indicate a score of 0)</th>
<th>Number of muscles affected (Number of carcases affected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M. cutaneus trunci et omobrachialis</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. trapezius cervicalis</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. trapezius thoracis</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. deltoideus</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. infraspinatus</td>
<td>1 1</td>
<td>4 (3)</td>
</tr>
<tr>
<td>M. triceps brachii (caput laterale)</td>
<td>1 2</td>
<td>2 (2)</td>
</tr>
<tr>
<td>M. teres minor</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. triceps brachii (caput longum)</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. tensor fasciae antibrachii</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. extensor carpi radialis</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. extensor digiti tertii proprius</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. extensor digitorum communis</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. extensor digit quarti proprius</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. extensor carpi ulnaris (s. ulnaris lateralis)</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. adductor pollicis longus (s. extensor carpi obliquus)</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. omotransversarius</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. rhomboideus</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>M. serratus ventralis cervicis</td>
<td>1</td>
<td>1 (1)</td>
</tr>
<tr>
<td>M. serratus ventralis thoracis</td>
<td>1</td>
<td>1 (1)</td>
</tr>
<tr>
<td>M. pectoralis profundus</td>
<td>1</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Muscle</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>M. pectoralis superficialis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. supraspinatus</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>M. biceps brachii</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. teres major</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. coracobrachialis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. subscapularis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. brachialis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. brachiocephalicus</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>M. triceps brachii (caput mediale)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. flexor carpi radialis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. flexor carpi ulnaris</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. flexor digitorum sublimis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. flexor digitorum profundus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. anconaeus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. serratus dorsalis cranialis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. scalenus dorsalis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. cervicothyoideus (s. omohyoideus)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. longissimus cervicis</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>M. splenius</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>M. sternocephalicus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. scalenus ventralis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. longissimus et atlantis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. intertransversarius longus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. semispinalis capitis (s. complexus)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. rectus capitis dorsalis major</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. obliquus capitis caudalis</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>M. rectus thoracis (s. transversus costarum)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. transversus thoracis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. longus colli</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mm. multifidus cervicis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. obliquus capitis cranialis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. rectus capitis ventralis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(s. rectus capitis ventralis minor)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. rectus capitis lateralis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M. rectus capitis dorsalis minor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diaphragm</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

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. peroneus tertius, M. extensor digitorum longus, M. extensor digitorum brevis, M. extensor digitii tertii proprius (pedis).
*** The flexor digitorum profundus (pedis) arises by the heads of these three muscles.

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.

4.2.4 Discussion

From the dissection of eight fallow deer carcases 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
carcase 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 %\(^1\) 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\(^2\),
- *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 carcase 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.

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1 Proportions expressed as percentages of commercial cuts extrapolated
   from work on the ox, Butterfield and May (1966).
2 Sometimes referred to as ‘knuckle’ or ‘thick flank’.
4.3 The distribution of ecchymosis throughout the muscles of the hindquarter, loin, and shoulder (M. supraspinatus)

4.3.1 Introduction

The commercial boning out of deer carcases 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 the current study, a number of whole venison carcases were inspected at commercial abattoirs 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 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 carcase, 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 these muscles also, as indicators of ecchymosis throughout other hind leg primal.

4.3.2 Materials and methods

4.3.2.1 Data source

Ecchymosis scores for the loins, hind leg primal, and one shoulder muscle determined using the boning room grading method previously described (Chapter 3, page 44), were combined for analysis to determine relationships between muscles regarding both incidence and severity of ecchymosis. The data was retrieved from the trials which investigated electrical stunning methods (Chapter 8, page 188), and various combinations of stunning and slaughter methods (Chapter 9, page 208).
4.3.3 Results

When there was little or no ecchymosis (Grade 0 or 1) in the left round \((n= 208)\) of a carcase, between 86 % and 99 % of the time there was no ecchymosis worse than grade 1 in either of the loins, rumps, silversides, \(M. \text{semitendinosus}\), topsides, or \(M. \text{supraspinatus}\). However, of the carcases where ecchymosis greater than grade 1 was exhibited in the left round \((n= 81)\), between 26 % and 77 % of the time there was no ecchymosis greater than grade 1 in the other muscles. In carcases where the left round exhibited ecchymosis of a score greater than grade 1, there was almost always (89 % to 95 % of the time) some \((\geq \text{grade 1})\) ecchymosis in the other round, both loins, and both rumps (Table 3).

Table 3: The number of carcases exhibiting ecchymosis in the commercially valuable hind leg primal, \(M. \text{supraspinatus}\), and loins (grade 0 or 1, \(>0, >1\)) expressed as a percentage of the carcases which exhibited ecchymosis (grade 0 or 1, \(>1\)) in the left round.

<table>
<thead>
<tr>
<th>Comparative muscle ecchymosis score</th>
<th>Left round ecchymosis score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 or 1</td>
</tr>
<tr>
<td></td>
<td>(n = 208)</td>
</tr>
<tr>
<td>Right round</td>
<td>90.9</td>
</tr>
<tr>
<td>Left loin</td>
<td>90.9</td>
</tr>
<tr>
<td>Right loin</td>
<td>86.5</td>
</tr>
<tr>
<td>Left rump</td>
<td>90.9</td>
</tr>
<tr>
<td>Right rump</td>
<td>89.9</td>
</tr>
<tr>
<td>Left silverside</td>
<td>99.0</td>
</tr>
<tr>
<td>Right silverside</td>
<td>97.6</td>
</tr>
<tr>
<td>Left (M. \text{semitendinosus})</td>
<td>97.1</td>
</tr>
<tr>
<td>Right (M. \text{semitendinosus})</td>
<td>95.7</td>
</tr>
<tr>
<td>Left topside</td>
<td>98.0</td>
</tr>
<tr>
<td>Right topside</td>
<td>95.7</td>
</tr>
<tr>
<td>Left (M. \text{supraspinatus})</td>
<td>95.4</td>
</tr>
<tr>
<td>Right (M. \text{supraspinatus})</td>
<td>95.2</td>
</tr>
</tbody>
</table>

When ecchymosis greater than grade 1 was exhibited in the left round \((n= 81)\), there was almost always (98 % of the time) some \((\geq \text{grade 1})\) 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 primal or loins was counted (Table 4).
Table 4: The number of carcases 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 carcases which exhibited ecchymosis (grade 0 or 1, > 1) in the left round.

<table>
<thead>
<tr>
<th></th>
<th>Left round ecchymosis score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 or 1</td>
</tr>
<tr>
<td>Number of carcases</td>
<td>n= 208</td>
</tr>
<tr>
<td>Comparative muscle ecchymosis score</td>
<td>0 or 1</td>
</tr>
<tr>
<td>Loins and rumps</td>
<td>79.81</td>
</tr>
<tr>
<td>Silversides &amp; topsides</td>
<td>89.42</td>
</tr>
</tbody>
</table>

In a number of trials in the current study, the loins and rounds only were used to determine ecchymosis incidence throughout the carcase. Of the 123 carcases which exhibited ecchymosis greater than grade 1 in 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 were observed to diminish (52%, 49%, and 57% respectively) when only ecchymosis greater than grade 1 was counted for all muscles (Table 5).

Table 5: The number of carcases exhibiting ecchymosis in the silversides or topsides, left rump, and right rump (> 0, > 1) expressed as a percentage of the carcases which exhibited ecchymosis > 1 in the left round.

<table>
<thead>
<tr>
<th></th>
<th>% of carcases, with a total loin and round ecchymosis score &gt; grade 1 (n= 123), exhibiting ecchymosis in each of the other hind leg primals of; &gt; 0, or &gt; 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other hind leg primals ecchymosis score - &gt; 0</td>
<td>&gt; 1</td>
</tr>
<tr>
<td>Left rump</td>
<td>86.18</td>
</tr>
<tr>
<td>Right rump</td>
<td>86.18</td>
</tr>
<tr>
<td>Any silverside or topside</td>
<td>93.50</td>
</tr>
</tbody>
</table>

4.3.4 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 carcases were boned out prior to the inspection of the muscles. When a carcase 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 carcase exhibited ecchymosis greater than grade 1 in the left round, there was a higher than 85% chance that some (> grade 1) ecchymosis also
occurred in each of the loins and silversides, and higher than 50 % chance that ecchymosis greater than grade 1 occurred.

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

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 carcases, and in at least one of the other hind leg primal in 93 % of the carcases.

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 carcase including the loin and hind leg primal, was by the removal and inspection of those muscles via boning. On that basis, fallow deer venison should not be exported as whole carcases, particularly those from deer 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 carcases, the inspection of the round while attached to the carcase (referred to as the chiller grading method) could be considered as a method of determining the presence of ecchymosis throughout the other commercial cuts, and could be adopted by industry. The chiller grading method involved the inspection of the round, or more specifically the M. vastus lateralis, while attached to the carcase, after removal of the portion of the M. tensor fasciae latae which covered it.
In the current experiment, the round was inspected for ecchymosis after its removal from the hind leg (referred to as the boning room grading method), however, interpretation of the results was based on either little or no ecchymosis (Grade 0 or 1), or ecchymosis greater than grade 1 occurring. This was because generally, if the ecchymosis observed in the boning room was only of grade 1 severity, it would not have been detected using the chiller grading method, which took place in an abattoir chiller where poor lighting precluded an examination as could occur in the boning room. Thus in the current experiment, ecchymosis in the round recorded as greater than grade 1 severity, would probably have appeared as grade 1 in the chiller, and on this basis, in the commercial situation where there was any ecchymosis detected in the left round using the chiller grading method, there would 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.

Unfortunately, it is possible that some venison vendors would choose to export those carcases 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 meat exhibiting ecchymosis be exported, consideration should be given with respect to modifying the current inspection practices for deer.
4.4 The heart and lungs as indicators of ecchymosis in the skeletal muscles of fallow deer

4.4.1 Introduction

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 (MIRINZ, 1974) 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 carcase 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.

4.4.2 Materials and methods

4.4.2.1 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 carcase at the abattoir. Excess blood was wiped from the organs prior to inspection.

4.4.2.2 Data source

The 4 slaughter trials from which data was retrieved included trials 1 and 2 investigating the effect of electrical stunning method on ecchymosis in castrates and bucks respectively (Chapter 8, page 188), and two trials involving does which investigated the effect of stunning method and the interval between stunning and exsanguination on ecchymosis (Chapter 9, page 222).

80
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 occurred with either stunning method when 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.

4.4.2.3 Data analysis

The heart and lung data from all trials was analysed using analysis of variance 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 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.

4.4.3 Results

4.4.3.1 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 (refer to Chapter 8, page 188). 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 6: Heart, lung and skeletal muscle ecchymosis score for castrates.

<table>
<thead>
<tr>
<th>Body part</th>
<th>Ecchymosis scores</th>
<th>Mean ecchymosis score</th>
<th>± SEM</th>
<th>Percent affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart</td>
<td>0 1 2 3 4</td>
<td>1.4</td>
<td>0.23</td>
<td>86</td>
</tr>
<tr>
<td>Lung</td>
<td>10 9 2 0 1</td>
<td>0.8</td>
<td>0.21</td>
<td>56</td>
</tr>
<tr>
<td>Left round</td>
<td>7 5 4 5 1</td>
<td>1.4</td>
<td>0.28</td>
<td>68</td>
</tr>
<tr>
<td>Right round</td>
<td>2 12 3 2 3</td>
<td>1.6</td>
<td>0.26</td>
<td>91</td>
</tr>
<tr>
<td>Left loin</td>
<td>2 11 3 4 2</td>
<td>1.7</td>
<td>0.25</td>
<td>91</td>
</tr>
<tr>
<td>Right loin</td>
<td>4 9 2 4 3</td>
<td>1.7</td>
<td>0.29</td>
<td>82</td>
</tr>
</tbody>
</table>

Table 7: Heart, lung, and skeletal muscle ecchymosis scores for bucks.

<table>
<thead>
<tr>
<th>Body part</th>
<th>Ecchymosis scores</th>
<th>Mean ecchymosis score</th>
<th>± SEM</th>
<th>Percent affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart</td>
<td>19 2 0 0 0</td>
<td>0.1</td>
<td>0.07</td>
<td>10</td>
</tr>
<tr>
<td>Lung</td>
<td>17 1 2 1 0</td>
<td>0.6</td>
<td>0.27</td>
<td>19</td>
</tr>
<tr>
<td>Left round</td>
<td>10 5 3 3 0</td>
<td>0.9</td>
<td>0.24</td>
<td>52</td>
</tr>
<tr>
<td>Right round</td>
<td>5 7 5 4 0</td>
<td>1.4</td>
<td>0.23</td>
<td>76</td>
</tr>
<tr>
<td>Left loin</td>
<td>3 6 10 0 2</td>
<td>1.6</td>
<td>0.23</td>
<td>86</td>
</tr>
<tr>
<td>Right loin</td>
<td>2 10 3 6 0</td>
<td>1.6</td>
<td>0.22</td>
<td>90</td>
</tr>
</tbody>
</table>

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 or lung were observed to be reliable indicators of ecchymosis in the skeletal muscles (Table 6 and Table 7).

4.4.3.2 Does

Previous analysis of the skeletal muscle ecchymosis scores showed a significant (p< 0.01) slaughter treatment effect on ecchymosis in the skeletal muscles of the does (Chapter 9, page 222). There was also more ecchymosis exhibited in the skeletal muscles of the carcases from the first trial than in those from the second trial (Table 8 and Table 9).
Table 8: Heart, lung, and skeletal muscle ecchymosis scores for does from trial 1.

<table>
<thead>
<tr>
<th>Body part</th>
<th>Ecchymosis scores</th>
<th>Mean ecchymosis score</th>
<th>± SEM</th>
<th>Percent affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0     1     2     3     4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart</td>
<td>22    0     0     0     0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lung</td>
<td>9     6     0     0     7</td>
<td>1.5</td>
<td>0.38</td>
<td>59</td>
</tr>
<tr>
<td>Left round</td>
<td>15    3     0     3     1</td>
<td>0.7</td>
<td>0.27</td>
<td>32</td>
</tr>
<tr>
<td>Right round</td>
<td>15    2     2     2     1</td>
<td>0.7</td>
<td>0.27</td>
<td>32</td>
</tr>
<tr>
<td>Left loin</td>
<td>16    4     0     1     1</td>
<td>0.5</td>
<td>0.23</td>
<td>27</td>
</tr>
<tr>
<td>Right loin</td>
<td>15    3     3     0     1</td>
<td>0.6</td>
<td>0.23</td>
<td>32</td>
</tr>
</tbody>
</table>

Table 9: Heart, lung, and skeletal muscle ecchymosis scores for does from trial 2.

<table>
<thead>
<tr>
<th>Body part</th>
<th>Ecchymosis scores</th>
<th>Mean ecchymosis score</th>
<th>± SEM</th>
<th>Percent affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0     1     2     3     4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart</td>
<td>22    0     0     0     0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lung</td>
<td>13    7     1     1     0</td>
<td>0.5</td>
<td>0.17</td>
<td>41</td>
</tr>
<tr>
<td>Left round</td>
<td>20    1     1     0     0</td>
<td>0.1</td>
<td>0.10</td>
<td>9</td>
</tr>
<tr>
<td>Right round</td>
<td>19    1     2     0     0</td>
<td>0.2</td>
<td>0.13</td>
<td>14</td>
</tr>
<tr>
<td>Left loin</td>
<td>16    6     0     0     0</td>
<td>0.3</td>
<td>0.10</td>
<td>27</td>
</tr>
<tr>
<td>Right loin</td>
<td>18    3     0     1     0</td>
<td>0.3</td>
<td>0.15</td>
<td>19</td>
</tr>
</tbody>
</table>

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 an indicator 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 a reliable indicator 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, Table 9, Table 10, and Table 11) and this was consistent with the ecchymosis scores for the skeletal muscles (Table 8 and Table 9).

The data from each trial were similar with respect to the slaughter treatment effect on ecchymosis incidence in the lungs (Table 10 and Table 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 1 of the lungs from the does which were captive bolt stunned and exsanguinated after the short interval exhibited ecchymosis.

Table 10: Ecchymosis scores showing treatment effect on lungs of does from trial 1.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Lung ecchymosis scores</th>
<th>Mean ecchymosis score</th>
<th>± SEM</th>
<th>Per cent affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 1 2 3 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CB/D</td>
<td>5 0 0 0 1</td>
<td>0.67</td>
<td>0.67</td>
<td>17</td>
</tr>
<tr>
<td>CB/S</td>
<td>1 4 0 0 0</td>
<td>0.80</td>
<td>0.20</td>
<td>80</td>
</tr>
<tr>
<td>ES/D</td>
<td>0 0 0 6</td>
<td>4.00</td>
<td>0.00</td>
<td>100</td>
</tr>
<tr>
<td>ES/S</td>
<td>3 2 0 0 0</td>
<td>0.40</td>
<td>0.25</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 11: Ecchymosis scores showing treatment effect on the lungs of does from trial 2.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Lung ecchymosis scores</th>
<th>Mean ecchymosis score</th>
<th>± SEM</th>
<th>Per cent affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 1 2 3 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CB/D</td>
<td>5 0 0 0 0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CB/S</td>
<td>4 2 0 0 0</td>
<td>0.33</td>
<td>0.21</td>
<td>33</td>
</tr>
<tr>
<td>ES/D</td>
<td>0 3 1 1 0</td>
<td>1.60</td>
<td>0.40</td>
<td>100</td>
</tr>
<tr>
<td>ES/S</td>
<td>4 2 0 0 0</td>
<td>0.33</td>
<td>0.21</td>
<td>33</td>
</tr>
</tbody>
</table>

* CB captive bolt, D delayed interval, ES electrical stun, S short interval.

4.4.4 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 (Chapter 2, page 24), 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 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 carcase. From the results, the incidence of ecchymosis in the hearts was inconsistent with the incidence in the loins and rounds in the carcases of the does and bucks. With respect to the does, none were affected by ecchymosis in the heart, in contrast to some of the skeletal muscles being affected in 30% of the carcases. 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 bucks 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, just over 50% were accounted for by ecchymosis occurring in the lungs. In the bucks only 20% of the carcases 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 reliable indicators of ecchymosis incidence in the skeletal muscles of fallow deer.
4.5 The examination of internal body cavity muscles as indicators of ecchymosis in the other skeletal muscles of fallow deer

4.5.1 Introduction

Most of the previous studies on ecchymosis in sheep were based on the inspection of the externally visible muscle surfaces of the whole carcase, 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 and 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 carcase and showed the diaphragm to be a good indicator of more widespread ecchymosis throughout the carcase, and Thornton and Gracey (1974) considered the diaphragm to be the most frequently affected skeletal muscle in beef and sheep carcases.

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 tenderloins, comprised mainly of the *M. psoas major*, the intercostal muscles, the abdominal muscles, and the diaphragm.

From results presented earlier, the tenderloins and intercostals could be excluded as indicators of ecchymosis on the basis that out of 16 carcase 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 carcase 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 carcase.

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.

4.5.2 General materials and methods

4.5.2.1 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 carcase 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 tenderloins (*M. psoas major*). Similarly, ecchymosis in the diaphragm refers to that observed on the caudal 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 (Chapter 3, page 44). The method used will be nominated in each of the descriptions of the data sets that follow.
4.5.3 Commercial type D1 abattoir

4.5.3.1 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 described in Chapter 5 (page 137). Captive bolt stunning and the gash cut method of exsanguination were used, as previously described (Chapter 3, pages 58 and 54). 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 described in Chapter 3 (page 44). For each carcase inspected, only the higher of the left and right diaphragm ecchymosis scores was recorded.

4.5.3.2 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 carcases inspected, 69% exhibited ecchymosis in either the left or right diaphragm muscles, while only 28% of the carcases were affected by ecchymosis in the left round (Table 12). 34 of the 35 carcases, which exhibited ecchymosis in the round, also exhibited ecchymosis in the diaphragm. However, 52 of the carcases exhibited ecchymosis in the diaphragm, but did not exhibit ecchymosis in the round. 37 carcases had no ecchymosis in either the diaphragm or the round (Table 13).
Table 12: Diaphragm and round ecchymosis scores for 124 fallow deer slaughtered at a commercial type D1 abattoir.

<table>
<thead>
<tr>
<th>Body part</th>
<th>Ecchymosis scores</th>
<th>Number of carcases</th>
<th>Per cent affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 1 2 3 4</td>
<td>124</td>
<td>69</td>
</tr>
<tr>
<td>Diaphragm</td>
<td>38 41 25 16 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left round</td>
<td>89 23 11 1 0</td>
<td>124</td>
<td>28</td>
</tr>
</tbody>
</table>

Table 13: Cross tabulation showing ecchymosis scores for round and diaphragm of 124 fallow deer slaughtered at a type D1 commercial abattoir.

<table>
<thead>
<tr>
<th>Round ecchymosis score</th>
<th>Diaphragm ecchymosis score</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0 37 1 0 0 0</td>
</tr>
<tr>
<td>1</td>
<td>35 6 0 0 0</td>
</tr>
<tr>
<td>2</td>
<td>12 10 2 1 0</td>
</tr>
<tr>
<td>3</td>
<td>5 6 5 0 0</td>
</tr>
<tr>
<td>4</td>
<td>0 0 4 0 0</td>
</tr>
</tbody>
</table>

4.5.4 Commercial type B abattoir

4.5.4.1 Materials and methods

The diaphragm, abdominal, and left round ecchymosis scores were recorded from 220 fallow deer slaughtered at a type B commercial abattoir described in Chapter 5 (page 132). Electrical stunning and the gash cut method of exsanguination were used, as described in Chapter 3 (pages 58 and 54). The sex type of the deer was unknown. The left round was scored for ecchymosis using the chiller grading method described in Chapter 3 (page 44). For each carcase inspected, only the higher of the left and right diaphragm and abdominal muscle ecchymosis scores was recorded.

4.5.4.2 Results

26 % of the 220 carcases inspected had ecchymosis in the left round, compared with 35 % and 36 % having ecchymosis in the diaphragm and abdominal muscles respectively. 48 % of the carcases had ecchymosis in either the diaphragm or abdominal muscles (Table 14).

90
Table 14: Diaphragm, abdominal, and round ecchymosis scores for 220 fallow deer slaughtered at a commercial type B abattoir.

<table>
<thead>
<tr>
<th>Body part</th>
<th>Ecchymosis scores</th>
<th>Number of carcases</th>
<th>Per cent affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Diaphragm</td>
<td>143</td>
<td>65</td>
<td>10</td>
</tr>
<tr>
<td>Abdominal</td>
<td>141</td>
<td>66</td>
<td>13</td>
</tr>
<tr>
<td>Dia. &amp; Abd.*</td>
<td>114</td>
<td>53</td>
<td>34</td>
</tr>
<tr>
<td>Left round</td>
<td>162</td>
<td>51</td>
<td>6</td>
</tr>
</tbody>
</table>

* highest recorded score

When ecchymosis was counted as either present or not present, rather than by grade, of the 58 carcases 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 carcases with ecchymosis in the round were accounted for. Approximately half of the 162 carcases that did not have ecchymosis in the round, did have ecchymosis in the diaphragm or abdominal muscles (Table 15).

Table 15: Cross tabulation of ecchymosis scores for round, diaphragm, and abdominal muscles of 220 fallow deer slaughtered at a type B commercial abattoir.

<table>
<thead>
<tr>
<th>Ecchymosis present in indicator muscles</th>
<th>Diaphragm</th>
<th>Abdominal</th>
<th>Dia. &amp; Abd.*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Ecchymosis present in round</td>
<td>Yes</td>
<td>44</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>33</td>
<td>129</td>
</tr>
</tbody>
</table>

* highest recorded score used

4.5.5 Commercial type D2 abattoir (Research trial)

4.5.5.1 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, which involved 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. A full description of the trial can be seen in Chapter 9 (page 230). Loin and round ecchymosis scores referred to in the results, were determined using the boning room grading method described in Chapter 3 (page 44). The higher of the left and right ecchymosis scores recorded for each of the diaphragm and abdominal muscles was used for the analysis.

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.

4.5.5.2 Statistical analysis

Analysis of variance was used to determine if there was a slaughter treatment or sex type effect on ecchymosis expression in the diaphragm and abdominal muscles.

4.5.5.3 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 carcases. 26 % of the carcases were affected in the abdominal muscles (Table 16).

Table 16: Diaphragm, abdominal, and round ecchymosis scores for 72 fallow deer slaughtered at a commercial type D2 abattoir.

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

* highest ecchymosis score recorded

Similar to the slaughter treatment effect on ecchymosis in the loin and round, which was shown in Chapter 9 (page 230), 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 0.67 (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± 0.08) 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 0.96 (SEM± 0.21) compared with the does and bucks which recorded similar mean ecchymosis scores of 0.29 (SEM± 0.10) 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 17: Cross tabulation of ecchymosis scores for loin, round, diaphragm, and abdominal muscles of 72 fallow deer slaughtered at a type D1 commercial abattoir.

<table>
<thead>
<tr>
<th>Ecchymosis present in indicator muscles</th>
<th>Diaphragm*</th>
<th>Abdominal*</th>
<th>Dia. &amp; Abd.*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>28</td>
<td>44</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>Ecchymosis in left round</td>
<td>Yes</td>
<td>30</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>42</td>
<td>9</td>
</tr>
<tr>
<td>Ecchymosis in any round or loin</td>
<td>Yes</td>
<td>46</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>26</td>
<td>2</td>
</tr>
</tbody>
</table>

* ecchymosis present in either side or muscle

In 46 of the carcases, 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 carcases, and the diaphragm alone 26. The abdominal muscle used exclusively as the marker tissues would have accounted for only 18 of the 46 carcases in which one of the loins or rounds was affected. Of the 26 carcases 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 17).
Combining the diaphragm and abdominal muscle ecchymosis scores as an indicator of ecchymosis accounted for 22 of the 30 carcases which exhibited ecchymosis in the left round, the abdominals alone accounted for 16, and the diaphragm 19 (Table 17).

4.5.6 UWS-H abattoir (Research trials)

4.5.6.1 PART 1

Materials and methods

Diaphragm and abdominal muscle ecchymosis scores were recorded from two slaughter trials comprising 22 does each, conducted at the UWS-H abattoir in the second week of September (spring), and the last day of November (Chapter 9, page 222). The trials were 2 x 2 factorial designs, with treatment groups comprising electrical or captive bolt stunning, with long (30 seconds) or short (4 - 14 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 caused 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 described in Chapter 3 (page 44).

Results

None of the 44 carcases exhibited ecchymosis in the abdominal muscles, and only 2 carcases exhibited ecchymosis in the diaphragm. The 2 carcases that exhibited ecchymosis in the diaphragm came from the first trial, and they both exhibited ecchymosis in each of the loins and rounds. 7 other carcases out of the 44 exhibited ecchymosis in the left round (Table 8 and Table 9, page 83).
4.5.6.2 PART 2

Materials and methods

Diaphragm ecchymosis scores from the carcases from two trials involving 23 and 26 does each were recorded. The trials were conducted at the UWS-H 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 trial (Chapter 9, page 215).

Results

7 of the carcases in trial 1, and 3 of the carcases in trial 2, exhibited ecchymosis in the diaphragm. 18 of the carcases in trial 1, and 9 of the carcases in trial 2, had ecchymosis in the left round. 20 carcases in trial 1, and 16 carcases in trial 2, had ecchymosis in at least one of the loins or rounds (Table 18). All of the carcases which exhibited ecchymosis in the diaphragm also had ecchymosis in the left round.

Table 18: Ecchymosis incidence in the diaphragm, rounds, and loins of 49 does slaughtered in UWS-H abattoir trials investigating slaughter methods.

<table>
<thead>
<tr>
<th>Number of carcases in trial</th>
<th>Number of carcases affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diaphragm</td>
</tr>
<tr>
<td>Trial 1</td>
<td>23</td>
</tr>
<tr>
<td>Trial 2</td>
<td>26</td>
</tr>
</tbody>
</table>

4.5.6.3 PART 3

Materials and methods

The diaphragms from the carcases 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 (Chapter 8, page 188).

Results

70% of the carcases 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 19).

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

Table 19: Ecchymosis incidence in the diaphragm, rounds, and loins of castrates, bucks, and does slaughtered in the UWS-H abattoir electrical stunning trials.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Sex type</th>
<th>Number of carcases in trial</th>
<th>Number of carcases affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Diaphragm</td>
</tr>
<tr>
<td>Trial 1</td>
<td>Castrate</td>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td>Trial 2</td>
<td>Castrate</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>Trial 3</td>
<td>Buck</td>
<td>17</td>
<td>9</td>
</tr>
<tr>
<td>Trial 4</td>
<td>Doe</td>
<td>23</td>
<td>5</td>
</tr>
</tbody>
</table>

4.5.7 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 carcase. In some trials, the incidence of ecchymosis in the diaphragm was twice that which occurred in the skeletal muscles. On this basis, whole carcases should not be condemned based on the presence of ecchymosis in the diaphragm or abdominal muscles.

Excluding the carcases from the trials conducted at the UWS-H abattoir, over all the other trials combined, 243 carcases exhibited no ecchymosis in either the diaphragm or abdominal muscles. Of these carcases, 28% exhibited ecchymosis in the left
round. At worst, the proportion of carcases 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 likelihood of skeletal muscle ecchymosis being present in groups of carcases, in which little or no ecchymosis is detected in the diaphragm or abdominal muscles.
4.6 Conclusions

The first step toward the development of a commercially practicable ecchymosis grading system for whole fallow deer carcases, was to determine the most frequently and severely affected skeletal muscles. From the complete dissection of a number of fallow deer carcases (Chapter 4, page 69), it was shown that the most frequently affected muscles of the carcase were unfortunately those which also sold 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 the *M. supraspinatus* and *M. infraspinatus*. Ecchymosis in these 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.

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\(^3\) Proportions expressed as percentages of commercial cuts extrapolated from work on the ox, Butterfield and May (1966).

\(^4\) Sometimes referred to as 'round' or 'thick flank'.

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From the results of the dissection work it was clear that specific muscles or organs used as inspection sites on a whole carcase basis to indicate more generalised ecchymosis incidence, would need to indicate as accurately as possible the presence of ecchymosis 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 reliability 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. There was no slaughter treatment effect reflected in the incidence of ecchymosis in the hearts or lungs of the castrates or bucks, and this was consistent with the skeletal muscle ecchymosis results discussed elsewhere (Chapter 8, page 188). 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 or bucks, were the heart and lungs demonstrated 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 (4 - 14 second) interval between stunning and exsanguination, following either captive bolt or electrical stunning. All the deer were exsanguinated using the thoracic stick method. 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. With 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 into 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 castrates, that the lungs are not reliable indicators of the presence of ecchymosis in the skeletal muscles of fallow deer.

Two points of interest arose from the results, with respect 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 carcase 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 carcase.

The use of a system similar to the MIRNZ ecchymosis grading system for sheep for indicating ecchymosis incidence in valuable commercial venison cuts, using the diaphragm and abdominal muscles as sites for inspection on a whole carcase, had little merit for use in the deer industry. In over half the carcases 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 carcases from deer slaughtered at one abattoir (UWS-H), of those carcases examined in the current study which did not exhibit ecchymosis in the diaphragm or abdominal muscles (n= 243), the proportion of carcases 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 presence of skeletal muscle ecchymosis that could be expected in a consignment of carcases that exhibited 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 carcase, including the loin and hind leg primal, 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 carcase basis, particularly carcases processed at abattoirs which use methods demonstrated in the current study to cause high incidences of ecchymosis. The results showed the round removed from the whole carcase to be a good indicator of ecchymosis in the other hind leg primal 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 carcases, the inspection of the round attached to the carcase, after removing the *M. tensor fasciae latae*, could be considered a relatively accurate means of predicting the presence of ecchymosis in the other commercial cuts, on a whole carcase basis, and could be adopted by venison processors. This method required only the removal of the portion of the *M. tensor fasciae latae*, which covered the *M. vastus lateralis*. During the current study, hundreds of left rounds were able to be inspected, at rates of up to 200 carcases an hour using this method. In the current experiment, ecchymosis in the round was inspected after its removal from the carcase, 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 detected after the detachment of the round from the carcase, would not be easily visible via the *in situ* examination of the round, as this usually took place in an abattoir chiller where frost bite and poor lighting precluded the accuracy of examination that could occur in the boning room. Thus, ecchymosis greater than grade 1 in the round observed in the boning room, could be expected to have been exhibited as grade 1 only while the round was attached to the carcase in the chiller, and on this basis, in the commercial situation where there was any ecchymosis detected in the left round while attached to the carcase, 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 carcases were exported whole, this would be the amount of ecchymosis observed by the buyer upon processing the carcases overseas.

Unfortunately, it is possible that some vendors would choose to export those carcases 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 carcases were similar to those which would have been observed in badly affected sheep carcases, whereby ecchymosis was found in the eye muscle, the fillet, leg and shoulder (Kirton and Woods, 1976). However, in less severely affected sheep carcases, 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 the diaphragm was not at all affected by ecchymosis, but there was still ecchymosis in the hind leg primal and loin. It is possible that Kirton and Woods (1976) did not find more ecchymosis in the leg primal of less severely affected sheep carcases, because of their method of dissection, whereby they sliced the carcases into 1 cm 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 and 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 carcase. This contrasts with results from the current study including those involving the complete dissection of deer carcases, 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 carcases 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 “shoulder, ham, and loin” were referred to in the materials and methods. Should the results of the aforementioned authors have been based on the latter 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 and 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 carcase. The results of the present study on deer suggest that ecchymosis is more widespread in affected deer carcases, a result that agrees with observations in previous studies (Lambooy, 1986; cited in Smulders, 1989), 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.
4.7 The effect of pré-stun restraint on the incidence and distribution of ecchymosis in fallow deer carcases

4.7.1 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 (Chapter 5, page 112) 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 in Chapter 5 (page 129), 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 (plate 20, page 57). The knocking box was built specifically for deer the size of fallow deer, with internal measurements of approximately 120 cm in length, 35 cm wide, and 90 cm 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. Deer were hung and thoracic stuck within 8 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 carcases 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 (Chapter 5, page 134) was associated with a type B abattoir, using electrical stunning and gash cut exsanguination, with deer held in a v-restraining conveyer system previously described (Chapter 3, page 55). Based on anecdotal reports from processors, and the results from the dissection of deer carcases, all of which were slaughtered in the same manner, ecchymosis in carcases 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 (Chapter 2, page 24). Compared with the tonic phase induced by the captive bolt used in the type E abattoir, 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 and 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 (plate 19, page 56). 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.

4.7.2 Materials and Methods

4.7.2.1 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.

4.7.2.2 Slaughter treatments

All deer were slaughtered at the UWS-H abattoir and electrically stunned in the v-drop floor crush previously described (Chapter 3, page 59). 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 400 volts for 1 second, and exsanguinated using the gash cut method approximately 10 seconds after stunning.
4.7.2.3 Measurements

Ecchymosis incidence was determined by the boning room grading method as previously described (Chapter 3, page 44).

4.7.2.4 Statistical analysis

Muscles were considered individually as affected or not affected by ecchymosis. Data was then analysed using the Chi-squared test.

4.7.3 Results

Observations of ecchymosis expression in the loin, round, rump, diaphragm and abdominal muscles are shown in Table 20.

Table 20: Ecchymosis scores for fallow deer subjected to normal and extra restraint at the time of stunning. (abd. = abdominal, diaph. = diaphragm, Cast. = Castrate)

<table>
<thead>
<tr>
<th>Slaughter treatment</th>
<th>Ecchymosis scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left loin</td>
</tr>
<tr>
<td>Normal restraint</td>
<td></td>
</tr>
<tr>
<td>group</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Extra restraint</td>
<td></td>
</tr>
<tr>
<td>group</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

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.

4.7.4 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 trials reported in Chapter 9 (page 230), 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 and 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 the treatments used by Lambooy and Sybesma (1988). 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 and Sybesma, 1988). Not surprising then, the results of the current study did not reflect those of Lambooy and 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 latter 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 carcase. 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 (Chapter 3, page 55) 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 carcases in the M. triceps brachii, which serves to extend the fore limbs caudal. As shown from the dissection of deer carcases, in only two carcase sides out of 16 did the M. triceps brachii 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.
Chapter five:

The venison processing sector and Quality Improvement

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5.1 Introduction

5.1.1 The adoption of technology - Reducing ecchymosis

The current study was commissioned by the Rural Industries Research and Development Corporation (RIRDC) on behalf of the elected representatives of the deer industry of Australia (DIAA), under the national organisational structure previously described (Chapter 1, page 7). 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 study investigated 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; Chambers and Ghildyal, 1985; Bawden et. al., 1985; Roling, 1988; Scoones and Thompson, 1993) and a number of conceptual models were 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 12) 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 12: Transfer of Technology (After Roling, 1988)**

The organisational structure of the Australian deer industry Research and Development (R&D) sector (Chapter 1, page 7) 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 (Chambers, 1983; Chambers and Ghildyal, 1985; Bawden et. al., 1985). The problem apparent with the TOT model in the third world context was that the bureaucrats, scientists and technologists, who generally came from Western developed nations, developed technologies in isolation from the intended recipients, who came from a completely different social, political, economic and cultural background. As a result, many of the technologies derived from the research were deemed politically, culturally or economically unsuitable and were never adopted. This situation led to a new philosophical approach to R&D, typified by the “Farmer first - farmer last” model (Figure 13), 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 13: Farmer first - Farmer last, a new paradigm for agricultural research (After Chambers and Ghildyal, 1985).

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 14) 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.

![Diagram of the 'top down' research and development structure.](image)

**Figure 14:** 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.
5.1.2 Quality control, Quality Assurance, and 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 15) 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.

In relation to Figure 15, 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.
<table>
<thead>
<tr>
<th>Types of Management Systems</th>
<th>Relationship to -Consumers and/or Competitors</th>
<th>Impact on Operation</th>
<th>Focus</th>
<th>Attitude Change Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Improvement</td>
<td>Standard Setter</td>
<td>Ahead of Crisis</td>
<td>Process required for Constant Improvement</td>
<td>'I must always strive to Improve'</td>
</tr>
<tr>
<td>Quality Assurance</td>
<td>Standard Taker</td>
<td>Constantly reacting to Crises</td>
<td>Technology required for Production</td>
<td></td>
</tr>
<tr>
<td>Quality Control</td>
<td></td>
<td></td>
<td>Technology required for Production</td>
<td>'I just need to meet Specifications'</td>
</tr>
</tbody>
</table>

Figure 15: Beyond Quality Assurance (Falepau and Mulley, 1996)

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.
5.2 The participative approach in general

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 (Chapter 7, page 159; Chapter 9, page 230) 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 an 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 regard 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.
5.3 Attempts at industry collaboration

5.3.1 Introduction

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.

5.3.2 Materials and methods

5.3.2.1 Ecchymosis recording systems

Methods of contact

The first contact made with processors and farmers was via an article published in the Australian Deer Farmer (1996) 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 RIRDC Deer Products R&D newsletter (1997) 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.

5.3.2.2 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 UWS-H research team had been contacted by the processors during the 18 months the current project had been operating. The UWS-H team were not made aware of the proposal until notified by the RIRDC.

In a subsequent meeting convened by the UWS-H 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 UWS-H project. In collaboration with the UWS-H team it was determined that the South Australian processors would record incidences of ecchymosis in deer carcases 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 3 months prior to changes being made to the existing slaughter system as that was the time required to make the infrastructural changes, and 12 months after. RIRDC project BRN-1A funded the modifications to the abattoir infrastructure and the contribution from the processors involved 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 current study and included;

- (processor 1) origin of deer, handling frequency prior to slaughter, behavioral response to handling, sex type, age, carcase fat score, number of rounds 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 carcase fat score and 24 hour pH. Ecchymosis in all commercial cuts was recorded voluntarily and corresponded to each individual carcase.

5.3.2.3 Experiments conducted at commercial premises

UWS-H trials

After limited cooperation from the commercial venison processing sector was forthcoming, the UWS-H abattoir was upgraded and a license to slaughter deer for domestic market consumption was obtained. A contractual agreement for the sale of whole carcases used in experiments conducted at the UWS-H abattoir was established with a venison vendor who operated a boning room in close proximity to the abattoir. Approximately 130 fallow deer carcases from 5 trials were graded for ecchymosis at the vendors boning room and those carcases 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 carcases 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 UWS-H abattoir trials one experiment involving 79 fallow deer was conducted at a type D2 abattoir described in later in this chapter (page 137) and affiliated boning room. The carcases 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.
5.3.3 Results

5.3.3.1 Ecchymosis recording systems

The article published in the Australian Deer Farmer (1996) and the RIRDC Deer Products R&D newsletter (1997) to initiate recording of ecchymosis by abattoirs, boning rooms and processors produced no response.

Following phone and mail contact made with the 6 export and 5 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 stated 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 UWS-H 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 an 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 continual attempts by the research team to find out when deer were being killed, cooperation from industry was negligible.

Over the two years following visits to the 3 export and 3 domestic boning rooms no information regarding the incidence of ecchymosis was recorded. The UWS-H 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. This was despite numerous follow up phone calls being made by the UWS-H
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.

5.3.3.2 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-1A) 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 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-1A) is presented on page 131.

5.3.3.3 Experiments conducted at commercial premises

UWS-H 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

9 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.
5.3.4 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) 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 UWS-H 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 carcases 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\(^5\), 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 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

\(^5\) Described as 'farmer' in the model put forward earlier.
current study, presented at national deer industry forum\(^6\) 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 UWS-H 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-1A), 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-1A) 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-1A) 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.
5.4 Slaughter system case studies - identifying the potential for Quality Improvement

5.4.1 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. Carcases were inspected and graded for ecchymosis at commercial abattoirs and boning rooms using the ‘chiller’ method developed during this study (Chapter 3, page 44), or during the boning of carcases during which some of the commercial cuts were inspected.

The five slaughter systems encountered during the current 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 carcases.

5.4.2 Slaughter system case studies

5.4.2.1 Case study 1: Type A (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 carcases to butcher shops and restaurants in their home towns towards the end of the investment phase (Chapter 1, page 7). 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 carcases 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, 1996) 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 being shackled and hoisted by a hind leg.

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

Recorded incidences of ecchymosis

As a condition of project (BRN-1A), which was expected to be conducted concurrently with the current study, limited data recorded on the prevalence of ecchymosis in carcases 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 3 month period. 17% exhibited ecchymosis in the left round although none of the scores were greater than grade one.
5.4.2.2 Case study 2: Type B (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 changed, including 1) the privatisation of many of these abattoirs which had initially been owned by local county councils, and 2) 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.

Carcase 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 carcases 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 carcases were then returned to Victoria for processing. The vendors often saw nothing of an entire consignment except for the relevant paperwork. Seldom did one company control both the slaughter and boning out procedures, even when the carcases 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 carcases.

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, carcase weight, carcase number, owner, and species was attached to the carcase. This enabled the venison vendor, for whom the deer were slaughtered, to trace the carcases 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 carcases. One inspector at a time was responsible for inspecting the carcases 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 carcases were examined for the presence of ecchymosis (Table 21) using the ‘chiller’ grading method previously described (Chapter 3, page 44). The carcases 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 21: Ecchymosis observed in the carcasses from fallow deer slaughtered at a large multi-species abattoir by electrical stunning and the gash cut method of exsanguination.

<table>
<thead>
<tr>
<th>Month</th>
<th>Ecchymosis grades (number of deer affected for each grade)</th>
<th>Number of deer/mob</th>
<th>Weight range</th>
<th>% of mob with ecchymosis ≥ 1</th>
<th>% of mob with ecchymosis ≥ 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb</td>
<td>32 28 10 6 3</td>
<td>82</td>
<td>27-42</td>
<td>57</td>
<td>23</td>
</tr>
<tr>
<td>Feb</td>
<td>85 7 1</td>
<td>93</td>
<td>22-60</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Feb</td>
<td>40 32 11</td>
<td>83</td>
<td>26-52</td>
<td>52</td>
<td>13</td>
</tr>
<tr>
<td>Feb</td>
<td>54 3</td>
<td>57</td>
<td>17-27</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Feb</td>
<td>45 5</td>
<td>50</td>
<td>19-56</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>259 75 22 6 3</td>
<td>365</td>
<td>29</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

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 claimed to reduce ecchymosis also.

5.4.2.3 Case study 3: Type C (large vertically integrated enterprise)

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 into 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. Often, an electric goad was used to move deer up 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.

Carcase 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 veterinarian and one meat inspector were employed on the slaughter floor and about 15 staff. Tagging of carcases was the same as at type A
abattoirs. Carcases 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 carcase. The tags were then removed prior to entry of the carcases 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. Slaughter of these deer began an hour after they arrived 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.

5.4.2.4 Case study 4: Type D (deer and ratite abattoirs)

Two types of abattoirs came under this category, those built originally for the slaughter of emus 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 designed to meet requirements for 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 5 or 6 staff, could slaughter approximately 70 red deer, or 80 fallow deer. Lairage capacity at the D2 abattoir could cater for little more than one day’s 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 in 1996. Subsequently, although alternative slaughter facilities became available in 1997-98, vendors slaughtering at type D1 abattoirs generally continued to do so, and deer were frequently transported to these abattoirs from distances of over 8 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 mushroom head captive 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 5 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 the initiation of exsanguination was reduced to approximately 10 seconds.

Carcase processing

At either type D abattoir, carcase processing was under the control of the abattoir management, with the D1 abattoir having a boning room attached, whilst 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 carcase tags. At the D2 abattoir, only HCW’s were recorded on the daily kill sheet and carcase 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 carcases of 134 fallow deer (Table 22) and 94 red deer (Table 23) were examined for the presence of ecchymosis using the ‘chiller’ grading method previously described (Chapter 3, page 44). 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 22: Ecchymosis scores recorded from fallow deer slaughtered at a deer and ratite abattoir by shooting and gash cut exsanguination.

<table>
<thead>
<tr>
<th>Kill</th>
<th>Farm</th>
<th>Ecchymosis grades (number of deer affected)</th>
<th>Number of deer/mob</th>
<th>Live weight range (kg)</th>
<th>% of mob with ecchymosis ≥ grade 1</th>
<th>% of mob with ecchymosis ≥ grade 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>37 14 6 1</td>
<td>58</td>
<td>40-53</td>
<td>36</td>
<td>12</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>9</td>
<td>9</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>34 3 2</td>
<td>39</td>
<td>-</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>8 6 3</td>
<td>17</td>
<td>46-54</td>
<td>53</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>10 1</td>
<td>11</td>
<td>45-57</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>98 24 11 1</td>
<td>134</td>
<td>27</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>
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.

Table 23: Ecchymosis scores recorded from red deer slaughtered at a deer and ratite abattoir by shooting and gash cut exsanguination.

<table>
<thead>
<tr>
<th>Kill</th>
<th>Farm</th>
<th>Ecchymosis grade</th>
<th>Total</th>
<th>Live weight range (kg)</th>
<th>% of mob with ecchymosis ≥ grade 1</th>
<th>% of mob with ecchymosis ≥ grade 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>53</td>
<td>53</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>40 1</td>
<td>41</td>
<td>-</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>93</td>
<td>1</td>
<td>94</td>
<td></td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

The mean circulating testosterone concentration for the 37 fallow 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.

5.4.2.5 Case study 5: Type E (purpose built fallow deer abattoir)

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.

Carcase 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 carcases had grade 1 ecchymosis in the shoulder (M. supraspinatus) of the left side only.

5.4.3 Discussion

In each of the slaughter systems studied the only meat quality parameter measured and recorded was carcase weight prior to chilling and in only one case study (type D1) were carcase 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 carcase 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 carcase 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 carcase 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 predisposed 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 5 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 1 minute after shooting with a .22 calibre firearm.
5.5 Conclusions

The Transfer of Technology (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.

The success of the TOT approach to R&D was contingent on two factors, the knowledge of the scientists and bureaucrats in prioritising research, and the dissemination of technologies. In the current study it appeared that the research was justifiably prioritised and a participative approach ensured the appropriateness of the
technologies developed. It has yet to be seen whether the R&D sector of the deer industry of Australia has the capacity to extend the technology towards adoption by the means manifest in the TOT paradigm. It was thought at the commencement of the current study that the participation of the commercial sector in the research process would facilitate the dissemination of research findings concurrent with the investigative process rather than this being reliant on traditional dissemination methods which due to the size of the deer industry and subsequent lack of dedicated extension personnel may have been limited to written media only. This was indicated in the deer industry R&D structure described previously (Chapter 1, page 7). Regarding the extension of research findings it was of interest to note that over the course of the entire study no invitations to address public forums were extended to the UWS-H research team despite one national and various state conferences taking place during that time. Factions were also apparent within the research and development sector itself, as manifest in the project (BRN-1A) in which extension personnel from that state had been involved with the processors concerned, yet neither the processors or the extension staff initiated any liaison with the current project despite their knowledge of it.

The participative approach to the extent that it was incorporated into the current study, may have extended research findings and it would be of interest to determine after some time whether the adoption of alternative slaughter methods was greater in those abattoirs used by processors involved in the study than those which were not. It would also be of interest to the current study to determine whether the infrastructural changes that were made to the slaughter system with respect to the collaborative project (BRN-1A) continue to be used if the incidence of ecchymosis associated the changes is shown to be greater than occurred with the previous system.


Chapter six:

Slaughter methods and their associated rates of blood loss.

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6.1 Introduction

As discussed previously in the case study reports (Chapter 5, page 129), 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 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 onto 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 stunning and exsanguination method combinations. Electrical stunning was the method observed most often for the Muslim slaughter of fallow deer, and the gash cut method of exsanguination was always used. The use of a captive bolt or .22 calibre firearm, such as occurred at the type D1 abattoir mentioned above, 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),
• captive bolt stunning followed by incomplete severance of the extended neck (CG1).

6.2 Materials and methods

6.2.1 Animals

Data was collected from four separate trials. Two of the trials (Chapter 9, page 215) comprised 48 fallow does slaughtered at the UWS-H abattoir, one trial (Chapter 9, page 230) involved 72 deer comprised of equal numbers of castrates, does, and bucks slaughtered at a type D2 abattoir, and one trial (Chapter 7, page 169) also conducted at the UWS-H abattoir was comprised of 12 bucks only.

6.2.2 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.
6.2.3 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). The carcasses were also inspected for ecchymosis and these result are discussed in the relevant experimental sections.

6.2.4 Data analysis

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

6.3 Results

There was no excessive blood retention observed in the hide or pleural cavity. 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 (Figure 16).

Table 24: Predicted mean weights (g) of blood collected from five stunning and exsanguination method combinations.

<table>
<thead>
<tr>
<th>Method</th>
<th>Captive bolt</th>
<th>Electrical stun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic stick</td>
<td>1072.7</td>
<td>1458.7</td>
</tr>
<tr>
<td>Gash cut</td>
<td>684.5</td>
<td>463.7</td>
</tr>
<tr>
<td>Gash cut (1 side only)</td>
<td>-</td>
<td>228.5</td>
</tr>
</tbody>
</table>

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 24).
Figure 16: Weight of blood collected during the 10 seconds subsequent to the initiation of exsanguination in fallow deer slaughtered by 5 different combinations of stunning and exsanguination methods.

6.4 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 (338.2 g) than the electrically stunned group (995.0 g). 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 g), 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 (Chapter 3, page 54) this would have resulted in the significantly different rates of blood loss between the two methods of stunning.

In a subsequent trial investigating the effect of electrical and captive bolt stunning methods combined with either a long (25 - 30 seconds) or short (4 - 14 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 (Chapter 2, page 24). 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 (Chapter 2, page 24), 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 (Chapter 4, page 80; Chapter 9, page 222).

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 another trial (Chapter 7, page 159) conducted at a type B abattoir, the thoracic stick method of exsanguination was observed to reduce significantly the incidence of ecchymosis in the skeletal muscles of electrically stunned fallow deer compared with the gash cut method. In that trial exsanguination was initiated within 5 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, this resulted in blood being lost before it could return to the musculature and cause ecchymosis, whereas with the gash cut method, blood would have to return to circulation to reach the region of the exsanguination incision and escape. The results of the current study substantiate this proposition regarding blood distribution, and blood loss related to the site of incision, and the influence of these factors 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 (220.8 g). 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 vasoconstriction 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 (1976) 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. The same authors 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 (1976) 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 (Chapter 5, page 137) 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.
Chapter seven:

Methods of exsanguination

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7.1 The effect of gash cut and thoracic stick methods of exsanguination on ecchymosis in electrically stunned fallow deer

7.1.1 Introduction

In Chapter 6 (page 148) 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, where they were electrically stunned and exsanguinated using the gash cut method. During the case studies reported previously, it was suggested by a number of venison processors who had previously used other type B abattoirs, that if the gash cut method of exsanguination was replaced with, or followed shortly after by, the thoracic stick method, this would lead to a reduction in ecchymosis (Chapter 5, page 132). The same processors also referred 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 oesophagus 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 the release of blood from the thoracic cavity, which occurred as a result of weasand tying, was similar to that caused by 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. However, 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 caused by a greater rate of blood loss when compared with the gash cut method, which was shown previously in Chapter 6. Associated with this 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, and that a 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 experiments as reported in Chapter 6.

The notion of participative approaches to research in order to improve the relevance and subsequent adoption of new technologies was discussed in Chapter 5 (page 112). The “Farmer first Farmer last model” (Chambers and Ghildyal, 1985) was discussed as an example of a model for research and development projects with the potential for improving the design and adoption of technologies in situations where the researcher was from a significantly different cultural background to the intended user of the technology. Briefly, the model consisted of 4 stages;

1. Diagnosis of the problem by the farmer and researcher
2. Solutions sought from multidisciplinary sources
3. Adaptation and testing on farm or research facility, and
4. Farmer evaluation.

Also discussed in Chapter 5 was the possibility that reducing the prevalence of ecchymosis in fallow deer in Australia may require the adoption of technologies alternate to those previously used. The current study aimed to identify potential barriers to the adoption of new technologies and investigate the effect of a participative approach to experimentation on their adoption.

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7.1.2 Materials and methods

7.1.2.1 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 UWS-H 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± 0.6).

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± 0.5).

7.1.2.2 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 (Chapter 5, page 132) approximately 3 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.

7.1.2.3 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 the author, with the other half exsanguinated by the Muslim slaughterman, using the gash cut technique.

7.1.2.4 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.

7.1.2.5 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 to 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 carcases 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 its 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.

7.1.2.6 Measurements

Ecchymosis was scored using the boning room method (Chapter 3, page 44). 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.

7.1.2.7 Statistical analysis

Total ecchymosis score data were analysed using analysis of variance to determine slaughter treatment effect on ecchymosis expression.
7.1.3 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 25). Combining the data from both trials, the mean total ecchymosis score was 4.29 (SEM± 0.72) for the gash cut treatment group and 0.46 (SEM± 0.32) for the thoracic stick treatment group.

Table 25: Skeletal muscle ecchymosis scores for does and bucks exsanguinated by either gash cut or thoracic stick methods at a type B abattoir.

<table>
<thead>
<tr>
<th>Trial and sex type</th>
<th>Gash cut</th>
<th>Thoracic stick</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ecchymosis scores</td>
<td>Ecchymosis score</td>
</tr>
<tr>
<td></td>
<td>Left loin</td>
<td>Right loin</td>
</tr>
<tr>
<td>Trial 1 Does</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does</td>
<td>2 1 2 2 7</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>4 3 3 4 14</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>2 1 1 0 4</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>3 2 2 1 8</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>2 2 3 2 9</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>2 1 1 1 5</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>1 0 2 2 5</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>2 2 2 3 9</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>2 1 2 2 7</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>0 1 1 2 4</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>0 0 0 0 0</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>1 0 1 0 2</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carcases affected = 11</td>
<td>Carcases affected = 0</td>
</tr>
<tr>
<td>Trial 2 Bucks</td>
<td>2 2 0 0 4</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>1 0 0 0 1</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>0 0 0 0 0</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>0 0 0 0 0</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>1 2 1 1 5</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>1 1 1 4</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>1 1 1 4</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>2 1 1 5</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>1 1 1 4</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>1 1 1 4</td>
<td>2 2 0 0 2</td>
</tr>
<tr>
<td></td>
<td>0 0 0 0 0</td>
<td>2 2 1 1 6</td>
</tr>
<tr>
<td></td>
<td>0 0 0 0 0</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td></td>
<td>Carcases affected = 8</td>
<td>Carcases affected = 2</td>
</tr>
</tbody>
</table>

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

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 ± 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.

7.1.4 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.
In Chapter 6, 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 from the perspective of the Muslim slaughterman that 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 with the 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. This is discussed in full in Chapter 5 (page 126). 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 Chapter 9 (page 208).
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 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 predisposition to ecchymosis was explored further in experiments reported in Chapter 9 (page 230). 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.
7.2.2 Materials and methods

7.2.2.1 Animals

Twelve fallow bucks, aged over 2 years, were slaughtered in the trial in late 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 27.5 kgs (SEM± 0.4).

7.2.2.2 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.

7.2.2.3 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± 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, without exsanguination was approximately 60 seconds (Cook et. al., 1994a).
7.2.2.4 Measurements

Weight of blood lost from each animal for 10 seconds subsequent to the initiation of exsanguination was measured as previously described in Chapter 6 (page 152). As previously described (Chapter 3, page 43), circulating cortisol and testosterone concentrations were determined from blood samples collected from each deer at the time of exsanguination, ultimate pH was measured, and carcases were scored for ecchymosis using the boning room grading method. Carcases were also inspected for bruising. The interval between the initiation of exsanguination and the cessation of the heart function was monitored using a stethoscope.

7.2.2.5 Statistical analysis

Blood loss and heart function data was analysed for treatment effect using analysis of variance. No statistical analysis was required to determine treatment effect on ecchymosis.

7.2.3 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± 11.6) compared with 347.8 grams (SEM± 44.3) for the complete gash cut group (Table 26). These data are discussed further in Chapter 6 (page 148).

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 104.5 seconds (SEM± 4.0) than in the deer whose necks were not completely severed, which had a group mean interval of 131.5 seconds (SEM± 9.0).
7.2 The incomplete severance of the neck during the ritual slaughter of fallow deer and its effect on ecchymosis

7.2.1 Introduction

Previous experiments investigated the rates of blood loss associated with the gash cut and thoracic stick methods of exsanguination (Chapter 6, page 148), and the effect of these two methods on the incidence of ecchymosis. 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, and the thoracic stick exsanguination method was shown to be associated with a significantly lower incidence of ecchymosis when compared with the gash cut method. These experiments involved fallow deer 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 (Chapter 5, page 137), 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 on rates of blood loss (Chapter 6, page 148) and circulating testosterone and cortisol concentrations associated with slaughter and sex type (Chapter 9, page 208).
Table 26: Skeletal muscle ecchymosis scores and data from fallow deer exsanguinated by complete or incomplete severance of the neck.

<table>
<thead>
<tr>
<th>Slaughter treatment</th>
<th>Ecchymosis scores</th>
<th>Blood lost (grams)</th>
<th>pH</th>
<th>Heart duration (seconds)</th>
<th>Cortisol (ng/ml)</th>
<th>Testosterone (ng/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left loin</td>
<td>Right loin</td>
<td>Left round</td>
<td>Right round</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete gash cut (2 sides)</td>
<td>4 4 2 1</td>
<td>529.3</td>
<td>6.22</td>
<td>89</td>
<td>81.1</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>2 1 0 2</td>
<td>319.5</td>
<td>6.51</td>
<td>117</td>
<td>103.7</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>0 1 1 2</td>
<td>263.5</td>
<td>6.51</td>
<td>109</td>
<td>62.1</td>
<td>3.61</td>
</tr>
<tr>
<td></td>
<td>0 0 1 2</td>
<td>227.7</td>
<td>6.54</td>
<td>98</td>
<td>74.7</td>
<td>2.69</td>
</tr>
<tr>
<td></td>
<td>0 1 1 0</td>
<td>339.0</td>
<td>6.42</td>
<td>107</td>
<td>66.8</td>
<td>1.09</td>
</tr>
<tr>
<td></td>
<td>0 0 0 0</td>
<td>407.8</td>
<td>6.60</td>
<td>107</td>
<td>83.3</td>
<td>0.95</td>
</tr>
<tr>
<td>Carcasses affected = 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Incomplete gash cut (1 side) | 1 3 3 0 | 229.1 | 6.01 | 142 | 101.5 | 0.66 |
|                             | 1 0 0 1 | 166.7 | 6.28 | 135 | 95.1 | 1.31 |
|                             | 0 1 0 0 | 164.5 | 5.98 | 96 | 57.8 | 0.77 |
|                             | 0 0 1 0 | 193.4 | 6.81 | 143 | 101.2 | 1.44 |
|                             | 1 0 0 0 | 152.4 | 6.37 | 116 | 122.8 | 2.23 |
|                             | 0 0 0 0 | 162.6 | 6.27 | 157 | 62.4 | 1.38 |
| Carcasses affected = 5 |

There was no treatment effect on the incidence of ecchymosis apparent with 5 out of 6 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. Nor was any relationship observed between testosterone and cortisol levels. The mean circulating cortisol and testosterone concentrations were 84.4 ng/ml (SEM± 5.9) and 1.48 ng/ml (SEM± 0.26) respectively.

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

7.2.4 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 carcase. In previous experiments, the thoracic stick method of exsanguination was observed to significantly reduce ecchymosis in comparison with the gash cut method (Chapter 7, page 159) and it was proposed that this was due to the greater rate of blood loss associated with the former of the two methods (Chapter 6, page 148). 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 (Chapter 8, page 176). 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 (Chapter 2, page 40). 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 carcases would have been considered high, and in conjunction with the high incidence of bruising in the carcases, reflected the excessive exercise observed in the bucks prior to slaughter. The severity of the echymosis 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 predispose bucks to any greater severity of echymosis than might otherwise be exhibited. Clearly, the proposed association between excessive pre-slaughter stress, if measured by pH, bruising or behavioral observations, and echymosis 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 (see Chapter 8, page 188). 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 (Asher et. al., 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. Experiments reported in Chapter 9 (page 230), explore further 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.
Chapter eight:

Factors associated with the electrical stunning of fallow deer and their effect on ecchymosis.

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8.1 Introduction

Up until 1995, the slaughter of fallow deer in Australia was accommodated mainly by a number of large multi-species abattoirs using their existing sheep and goat slaughter systems, which 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 (plate 18, page 56). Some of these abattoirs incorporated the thoracic stick method of exsanguination into the slaughter system, which was claimed by a number of venison processors to reduce the incidence of ecchymosis compared with the gash cut method. These claims were confirmed in previous experiments (Chapter 7, page 158).

By the beginning of 1996, only one type B abattoir was available for the slaughter of deer and in accordance with its export accreditation status, all fallow deer, sheep, and goats were slaughtered to Muslim requirements using head only electrical stunning and the gash cut method of exsanguination. At the time, while not all Australian venison was exported to Muslim markets (Chapter 1, page 5), this method of slaughter was still preferred by venison vendors so that their venison could be sold to Muslim markets if others did not eventuate.

As discussed in Chapter 7, at the remaining type B abattoir, the Muslim slaughterman would not modify in any way the method of exsanguination used, in order to reduce the incidence of ecchymosis, leaving only the method of stunning able to be modified. Unfortunately, Muslim slaughter requirements precluded the use of all other potential methods of stunning, some of which had been shown to reduce the incidence of ecchymosis in other species of livestock (Chapter 2, page 18). Notwithstanding Muslim requirements, even in the event that this market became less significant to the Australian venison industry, the use of most of the alternative methods of stunning could also be precluded on the basis of either; establishment cost, operating cost, inability to be incorporated into existing slaughter systems, lack of knowledge regarding their application in deer and/or other species, or safety.
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 (Chapter 2). The treatments compared by Kirton and Frazerhurst (1983) included; ‘normal stunning’, which involved using one application of 0.75 amps for 1 second, ‘double stunning’ which involved two applications of 0.75 amps for 1 second at 10 to 20 minutes apart, and ‘light then normal stunning’, which involved one stun using 0.5 amps for 0.3 seconds followed by a ‘normal stun’ 10 seconds later. Kirton and Frazerhurst (1983) found that ‘double’ and ‘light then normal stunning’ 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 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 5 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.

The voltage and duration used for the stunning of fallow deer at the Type B abattoir described in Chapter 5, was observed during numerous visits to range between 110 and 150 volts for a duration of 1 second. However, 70 volts was claimed to have been used in a previous trial conducted by Grogan (1998) at the same abattoir, and it was suggested that this was the voltage commonly used. There have been no previous studies investigating the stunning of fallow deer at these voltages or duration. One of the aims of this study was to clarify the minimum voltage required, using a stun
current duration of 1 second, to induce an epileptiform seizure in fallow deer, as indicated by the immediate onset of a tonic spasm.

It is evident from the literature (Blackmore et al., 1993; Cook et al., 1994a and 1994b) that both current and duration are implicated in the successful induction of an epileptiform seizure in deer electrically stunned prior to slaughter. However, no work has been conducted to determine the relationship between these parameters and the incidence of ecchymosis in fallow deer. The current study investigated the effect of current, duration, and voltage and duration combinations, on the incidence of ecchymosis.

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 claimed 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. Considering cortisol as an indicator of responses to pre-slaughter stress in lambs, Pearson et al. (1977) measured cortisol, adrenaline, and noradrenalin in lambs in an attempt to determine whether different levels of these hormones could explain consistently higher incidences of ecchymosis at some abattoirs compared with others. Circulating cortisol concentrations were observed to be significantly less in lambs slaughtered at a small research abattoir, compared with a large works, and this was attributed to no dogs being used at the smaller abattoir, it was said to be quieter, and the lambs were
handled less (Pearson et. al., 1977). The different cortisol levels were not observed to effect the incidence of ecchymosis (Pearson et. al., 1977).

Heart rate in domestic livestock has been shown to be affected by stress (Cook and Jacobson, 1996), 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 heart rate during restraint had any effect on ecchymosis expression. In conducting the experiments reported in Chapter 7 (page 158), discussions with the resident Muslim slaughterman, 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 chapter sought to clarify this proposition.
8.2 Commercial electrical stunning of fallow deer

8.2.1 Introduction

At the commencement of the current study (1996), there was only one type B abattoir available to slaughter fallow deer from Queensland, NSW, Victoria and South Australia for export. At this abattoir all fallow deer were slaughtered 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 observed in case studies (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 used 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 were 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.

8.2.2 Materials and methods

8.2.2.1 Animals and slaughter treatment

A commercial line of fallow deer ($n=156$) was slaughtered at a type B abattoir, as previously described in Chapter 5. The deer were stunned using 150 volts for a duration of 1 second using a voltage-controlled device of the same specifications as the stunner described previously (Chapter 3, page 58, Chapter 8, page 177), with the exclusion of a permanent ammeter.
8.2.2.2 Measurements

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.

8.2.2.3 Analysis

The mean, minimum, maximum, and distribution of the peak stun currents recorded were determined.

8.2.3 Results

The peak stun currents recorded from 156 deer stunned using 150 volts for 1 second showed a normal pattern of distribution (Table 27). 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 the deer were observed to lapse into a tonic phase reaction typical of an epileptiform seizure and a state of insensibility.

Table 27: Distribution of peak currents recorded from head only electrical stunned fallow deer at a type B abattoir using 150 volts for 1 second.

<table>
<thead>
<tr>
<th>Peak stun current (amps.)</th>
<th>Number of animals recording various peak stun currents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>2 **</td>
</tr>
<tr>
<td>0.5</td>
<td>5 *****</td>
</tr>
<tr>
<td>0.6</td>
<td>25 **************************************************</td>
</tr>
<tr>
<td>0.7</td>
<td>33 ***************************************************</td>
</tr>
<tr>
<td>0.8</td>
<td>43 *****************************************************</td>
</tr>
<tr>
<td>0.9</td>
<td>22 ********************************************************</td>
</tr>
<tr>
<td>1.0</td>
<td>15 *****************************************************</td>
</tr>
<tr>
<td>1.1</td>
<td>5 *****</td>
</tr>
<tr>
<td>1.2</td>
<td>1 *</td>
</tr>
<tr>
<td>1.3</td>
<td>3 **</td>
</tr>
<tr>
<td>1.4</td>
<td>0</td>
</tr>
<tr>
<td>1.5</td>
<td>1 *</td>
</tr>
<tr>
<td>1.6</td>
<td>0</td>
</tr>
<tr>
<td>1.7</td>
<td>0</td>
</tr>
<tr>
<td>1.8</td>
<td>1 *</td>
</tr>
</tbody>
</table>
8.2.4 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.
8.3 The effect of stun current duration on ecchymosis in fallow deer

8.3.1 Introduction

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, compared with pigs stunned using 70 volts for 10 seconds. In that particular experiment, two electrical stunning parameters were involved; voltage and duration. The current experiment intended to determine the effect on ecchymosis expression, of stun current duration only, using a duration of either 1 or 3 seconds at 100 volts. 100 volts was the closest voltage possible with the device used, 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.

8.3.2 Materials and methods

8.3.2.1 Animals

Thirteen fallow deer castrates aged 16 months with an average HCW of 19.8 (SEM± 0.5) were slaughtered at the UWS-H abattoir in early April (autumn). The deer had been held at the UWS-H 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.

8.3.2.2 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.

8.3.2.3 Measurements

Peak current at stunning was recorded, and carcases were graded for ecchymosis using the boning room grading method previously described (Chapter 3, page 44). Deer were observed at stunning to determine whether the stun induced a typical tonic phase reaction as previously described (Chapter 2, page 24).

8.3.2.4 Statistical analysis

Using the total of the loin and round ecchymosis scores for each carcase, 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’ carcases were analysed using the Chi squared test.

8.3.3 Results

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

When only those carcases with a total loin and round ecchymosis score greater than 1 were considered affected by ecchymosis, a significant \( p < 0.01 \) treatment effect was observed, 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± 0.32), and at 3 seconds duration it was 2.34 amps (SEM± 0.15) (Table 28).
Table 28: Loin and round ecchymosis scores and peak stun currents for fallow deer stunned using 400 volts for either 1 or 3 seconds duration.

<table>
<thead>
<tr>
<th>Stun current duration (sec.)</th>
<th>Peak stun current (amps.)</th>
<th>Loin and round ecchymosis scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total loin and round ecchymosis score</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Left</td>
</tr>
<tr>
<td>1</td>
<td>1.02</td>
<td>12</td>
</tr>
<tr>
<td>1</td>
<td>3.5</td>
<td>8</td>
</tr>
<tr>
<td>1</td>
<td>1.82</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>2.41</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>2.31</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>2.32</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2.88</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2.32</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2.68</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>3.23</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>2.08</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>2.08</td>
<td>0</td>
</tr>
</tbody>
</table>

8.3.4 Discussion

The results suggest that head only electrical stunning using 100 volts for 1 second was not sufficient to render insensible 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.
8.4 The effect of electrical stunning voltage and duration on ecchymosis in fallow deer

8.4.1 Introduction

The experiment reported in the previous section showed stun current duration at 400 volts to have an effect on the incidence of ecchymosis in one group of fallow deer castrates slaughtered at the UWS-H abattoir. The use of a longer stun current duration to reduce the incidence of ecchymosis could be easily implemented commercially. However, the results of the previous trial were based on only 12 deer of similar age, weight and pre-slaughter history. In Australia, fallow deer made available for slaughter often vary considerably with regard to sex type, age, weight and pre-slaughter history and it was of interest to this study to determine whether the same stun current and duration effect would occur with different classes of animal and at different voltages.

In the previous experiment, an unsuccessful attempt was made to stun one deer using 100 volts for 1 second. In light of this, and the limited literature available, which only considered the minimum current duration at 1.0 and 1.3 amps (Cook et. al., 1994b) required to render insensible fallow deer, it was of interest to determine the minimum voltage, and its relationship to current duration, required for successful stunning. No literature exists on the effect of electrical stunning on the incidence of ecchymosis in deer.

A number of pre-slaughter events perceived by some researchers as being stressful to animals, were shown to affect the incidence of ecchymosis including; methods of goading, restraint, and transport (Calkins et. al., 1981; Lambooy and Sybesma, 1988). Pre-slaughter stress was also put forward in numerous technical publications (Chapter 2, page 40) as one of the factors contributing to the incidence of ecchymosis in a number of species of domestic livestock. However, only one study cited in the literature attempted to link any blood plasma constituents as indicators of pre-slaughter stress, to ecchymosis incidence. Pearson et. al. (1977) found differences in
cortisol levels between lambs slaughtered at two different locations, which reflected different levels of pre-slaughter stress perceived to be associated with each location. No relationship however was observed between cortisol levels and ecchymosis. It had also been shown that increased heart rate may indicate pre-slaughter stress associated with treatments such as restraint (Cook and Jacobson, 1996) but this was not related to ecchymosis either. The following section reports a series of slaughter trials investigating the effect of voltage and duration on ecchymosis expression in fallow castrates, bucks and does slaughtered at the UWS-H abattoir. In conjunction, measurements of a number of other parameters related to slaughter were made and discussed including; circulating cortisol and testosterone concentrations and heart rate during restraint.

During the current study alternative methods of head only electrical stunning for fallow deer were discussed with the Muslim slaughterman at a type B abattoir and the use of volatges higher than 150 volts was dismissed due to his belief that they would cause the heart beat to cease prematurely. No investigations of this phenomena were cited in the literature and so the interval between the stunning and the cessation of heart function was also monitored in the current study.

8.4.2 Materials and methods

8.4.2.1 Animals

Four separate consignments of deer were slaughtered at the UWS-H 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 29.

Table 29: Number, sex type, month of slaughter, and live weight for deer used in experiments investigating the effect of voltage and duration on ecchymosis.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Date of slaughter</th>
<th>Sex type</th>
<th>n</th>
<th>Mean live weight (kg) (SEM±)</th>
<th>Live weight range (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>August</td>
<td>Castrate</td>
<td>25</td>
<td>37.4 (0.37)</td>
<td>34.5 - 41.0</td>
</tr>
<tr>
<td>2</td>
<td>August</td>
<td>Castrate</td>
<td>22</td>
<td>47.6 (1.48)</td>
<td>40.0 - 63.5</td>
</tr>
<tr>
<td>3</td>
<td>October</td>
<td>Bucks</td>
<td>25</td>
<td>50.8 (1.83)</td>
<td>37.0 - 66.0</td>
</tr>
<tr>
<td>4</td>
<td>November</td>
<td>Does</td>
<td>23</td>
<td>47.8 (0.73)</td>
<td>42.0 - 53.5</td>
</tr>
</tbody>
</table>
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 UWS-H research farm. The deer were then maintained at the UWS-H 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 UWS-H farm. An attempt was made to collect blood from the deer via jugular venepuncture upon arrival at the UWS-H farm. However, this was aborted due to excessive aversive behaviour shown by the deer, to what would generally be considered 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 UWS-H 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 UWS-H 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 UWS-H farm in the first week of August and the first deer 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 mob was 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
UWS-H 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 UWS-H 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 UWS-H farm for six weeks. The does received no supplementary feed.

8.4.2.2 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 UWS-H abattoir and deer unit facilities were described previously (Chapter 3, page 59). 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 1, 2 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 of the deer using 100 volts for 3 seconds. Peak currents of 0.12 and 0.27 amps were achieved. Neither 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 the ecchymosis scores for these deer were excluded from the analysis.
8.4.2.3 Measurements

Stun voltage and duration were recorded as prescribed for each treatment group. 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 heart beat was monitored using the stethoscope and recorded also. Carcases were weighed just prior to chilling. The uterus of each doe was inspected at evisceration to determine pregnancy status. As previously described (Chapter 3, page 43), the peak stun current for each deer was recorded immediately after application of the current ceased. Blood plasma was collected from castrates and bucks 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, and circulating testosterone levels were determined from the samples taken at slaughter.

8.4.2.4 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 were 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 carcase, the data were square root transformed and analysed using analysis of variance. 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 heart beat.

Analysis of variance was used to analyse the effect of voltage and duration on peak stun current, and differences between trials with respect to heart rate prior to stunning, and the interval between stunning and heart cessation.

8.4.3 Results

8.4.3.1 Carcase weights

The highest and lowest HCW’s recorded for the castrates from trial 1 differed by 4.4 kgs, compared with those in trials 2, 3, and 4 which differed by 11.2 kgs, 14 kgs, and 17.5 kgs respectively (Table 30). The differences in weights of the carcases from the latter three trials reflected significant age variations between the deer, particularly the bucks (trial 3) and castrates (trial 2) as was observed also with respect to live weights presented earlier (Table 29).

Table 30: Number, sex type, month of slaughter, and HCW for deer used in experiments investigating the effect of voltage and duration on ecchymosis.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Date of slaughter</th>
<th>Sex type</th>
<th>n</th>
<th>Mean HCW (SEM±) (kg)</th>
<th>HCW range (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>August</td>
<td>Castrate</td>
<td>25</td>
<td>22.1 (0.2)</td>
<td>19.9 - 24.3</td>
</tr>
<tr>
<td>2</td>
<td>August</td>
<td>Castrate</td>
<td>22</td>
<td>27.0 (0.9)</td>
<td>23.0 - 37.0</td>
</tr>
<tr>
<td>3</td>
<td>October</td>
<td>Bucks</td>
<td>25</td>
<td>29.1 (1.0)</td>
<td>21.5 - 39.0</td>
</tr>
<tr>
<td>4</td>
<td>November</td>
<td>Does</td>
<td>23</td>
<td>24.6 (0.6)</td>
<td>19.8 - 31.0</td>
</tr>
</tbody>
</table>

8.4.3.2 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, 2 and 3 second duration data sets show two uncharacteristically low recordings for that voltage of 0.82 and 1.03 amps (Figure 17). 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 6 cm caudal to the ears rather than the normal position of less than 3 cm 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.

![Stun currents by voltage & duration](image)

Figure 17: Peak stun currents recorded for voltages of 100, 200, 300, or 400 volts, applied for a duration of 1, 2, 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 31). 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 ranged from ±0.05 (150v, 1 sec.) to ±0.25 (400v, 3 sec.) (Table 31).

Table 31: Peak stun currents recorded for stunning voltages and duration, ranging from 150 volts for 1 second, to 400 volts for 3 seconds.

<table>
<thead>
<tr>
<th>Stun voltage and duration.</th>
<th>Number of deer slaughtered</th>
<th>Peak stun currents (amps.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>volts (seconds)</td>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>150 (1)</td>
<td>8</td>
<td>0.501</td>
</tr>
<tr>
<td>150 (2)</td>
<td>7</td>
<td>0.559</td>
</tr>
<tr>
<td>150 (3)</td>
<td>8</td>
<td>0.628</td>
</tr>
<tr>
<td>200 (1)</td>
<td>8</td>
<td>0.909</td>
</tr>
<tr>
<td>200 (2)</td>
<td>8</td>
<td>1.023</td>
</tr>
<tr>
<td>200 (3)</td>
<td>6</td>
<td>1.090</td>
</tr>
<tr>
<td>300 (1)</td>
<td>8</td>
<td>1.636</td>
</tr>
<tr>
<td>300 (2)</td>
<td>8</td>
<td>2.170</td>
</tr>
<tr>
<td>300 (3)</td>
<td>8</td>
<td>2.368</td>
</tr>
<tr>
<td>400 (1)</td>
<td>8</td>
<td>2.925</td>
</tr>
<tr>
<td>400 (2)</td>
<td>7</td>
<td>3.087</td>
</tr>
<tr>
<td>400 (3)</td>
<td>5</td>
<td>2.726</td>
</tr>
</tbody>
</table>

8.4.3.3 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 32).

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 102.6 sec. (SEM± 4.9) and 88 sec. (SEM± 2.4) for each of the castrate trials and 92 sec. (SEM± 3.6) for the does (Table 33).
Table 32: Heart rates (beats per minute) of fallow deer restrained in a v-restrainer, recorded for a period of 10 seconds immediately prior to stunning.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Date of slaughter</th>
<th>Sex type</th>
<th>n</th>
<th>Mean heart rate (beats per minute (± SEM))</th>
<th>Range (beats per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>August</td>
<td>Castrate</td>
<td>25</td>
<td>111.2 (5.6)</td>
<td>123</td>
</tr>
<tr>
<td>2</td>
<td>August</td>
<td>Castrate</td>
<td>22</td>
<td>122.5 (5.6)</td>
<td>113</td>
</tr>
<tr>
<td>3</td>
<td>October</td>
<td>Bucks</td>
<td>12</td>
<td>114.0 (5.3)</td>
<td>66</td>
</tr>
<tr>
<td>4</td>
<td>November</td>
<td>Does</td>
<td>21</td>
<td>102.6 (2.6)</td>
<td>48</td>
</tr>
</tbody>
</table>

Table 33: 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.

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

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.

8.4.3.4 **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 as much as the castrates between the day before and at slaughter (+ 0.9 ng/ml) (Table 34).
Table 34: Circulating cortisol and testosterone levels in castrates and bucks recorded 20 hours prior to, and at slaughter.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Sex type</th>
<th>n</th>
<th>Cortisol (ng/ml)</th>
<th>Testosterone (ng/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Day before</td>
<td>At slaughter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SEM±</td>
<td>SEM±</td>
</tr>
<tr>
<td>1</td>
<td>Castrate</td>
<td>25</td>
<td>90.8</td>
<td>3.9</td>
</tr>
<tr>
<td>2</td>
<td>Castrate</td>
<td>22</td>
<td>64.6</td>
<td>3.9</td>
</tr>
<tr>
<td>3</td>
<td>Buck</td>
<td>25</td>
<td>72.6</td>
<td>3.6</td>
</tr>
</tbody>
</table>

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.

8.4.3.5 Order of slaughter

The time taken to slaughter between 20 and 25 fallow deer at the UWS-H 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.

8.4.3.6 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 all trials were pooled into one combined analysis. None of the factors accounted for in the analysis were shown to affect ecchymosis expression 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 35 shows the distribution of ecchymosis scores (loin and round totals) for each of trials 1, 2, 3, and 4, and Table 36 shows the same for all trial data combined.

Table 35: Number of carcasses affected by ecchymosis in each of 4 trials, for each possible total loin and round ecchymosis score ranging from 0 to 16. Trials investigated electrical stunning voltage and duration.

<table>
<thead>
<tr>
<th>Total loin and round ecchymosis score</th>
<th>Trial 1 number of carcasses affected (n=25) castrates</th>
<th>Trial 2 number of carcasses affected (n=22) castrates</th>
<th>Trial 3 number of carcasses affected (n=25) bucks</th>
<th>Trial 4 number of carcasses affected (n=23) does</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1 *</td>
<td>1 *</td>
<td>1 *</td>
<td>2 **</td>
</tr>
<tr>
<td>1-2</td>
<td>4 *****</td>
<td>2 **</td>
<td>6 *********</td>
<td>3 ***</td>
</tr>
<tr>
<td>3-4</td>
<td>5 *****</td>
<td>6 *********</td>
<td>6 *********</td>
<td>6 *******</td>
</tr>
<tr>
<td>5-6</td>
<td>8 ***********</td>
<td>3 ***</td>
<td>3 ***</td>
<td>2 **</td>
</tr>
<tr>
<td>7-8</td>
<td>4 ****</td>
<td>4 ****</td>
<td>4 *******</td>
<td>3 ***</td>
</tr>
<tr>
<td>9-10</td>
<td>1 *</td>
<td>2 **</td>
<td>1 *</td>
<td>1 *</td>
</tr>
<tr>
<td>11-12</td>
<td>1 *</td>
<td>2 **</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>13-14</td>
<td>1 *</td>
<td>2 **</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15-16</td>
<td>0</td>
<td>1 *</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 36: Number of carcasses affected by ecchymosis in 4 trials combined, for each possible total loin and round ecchymosis score ranging from 0 to 16. Trials investigated electrical stunning voltage and duration.

<table>
<thead>
<tr>
<th>Total loin and round ecchymosis score</th>
<th>Trials 1, 2, 3 and 4 (n=95) number of carcasses affected for each total loin and round score category</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5 *****</td>
</tr>
<tr>
<td>1-2</td>
<td>15 ****************************</td>
</tr>
<tr>
<td>3-4</td>
<td>23 ****************************</td>
</tr>
<tr>
<td>5-6</td>
<td>16 ****************************</td>
</tr>
<tr>
<td>7-8</td>
<td>14 ****************************</td>
</tr>
<tr>
<td>9-10</td>
<td>8 ****************************</td>
</tr>
<tr>
<td>11-12</td>
<td>9 ****************************</td>
</tr>
<tr>
<td>13-14</td>
<td>4 ****</td>
</tr>
<tr>
<td>15-16</td>
<td>1 *</td>
</tr>
</tbody>
</table>

From 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 35), 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 6 cm caudal to the ears, rather than the normal position of less than 3 cm 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 35), which was the group the deer came from, would also have been considered unremarkable.

Table 37: 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.

<table>
<thead>
<tr>
<th>Data source</th>
<th>Left round ecchymosis score (number of carcasses for each score)</th>
<th>Number of carcasses in each mob</th>
<th>% of carcases in each mob with left round ecchymosis score ≥ 1, or ≥ 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 1 2 3 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trials 1 - 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>30 14 17</td>
<td>95</td>
<td>67 38</td>
</tr>
<tr>
<td>32</td>
<td>28 10 6</td>
<td>82</td>
<td>57 23</td>
</tr>
<tr>
<td>85</td>
<td>7 1</td>
<td>93</td>
<td>9 1</td>
</tr>
<tr>
<td>40</td>
<td>32 11</td>
<td>83</td>
<td>52 13</td>
</tr>
<tr>
<td>54</td>
<td>3</td>
<td>57</td>
<td>50 0</td>
</tr>
<tr>
<td>45</td>
<td>5</td>
<td>50</td>
<td>10 0</td>
</tr>
<tr>
<td>Type B abattoir</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>14 6 1</td>
<td>58</td>
<td>36 12</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>9</td>
<td>0 0</td>
</tr>
<tr>
<td>34</td>
<td>3 2</td>
<td>39</td>
<td>12 5</td>
</tr>
<tr>
<td>8</td>
<td>6 3</td>
<td>17</td>
<td>53 18</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>11</td>
<td>9 0</td>
</tr>
<tr>
<td>Type D1 abattoir</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The overall incidence of ecchymosis observed in trials 1 to 4 was worse than in any mobs of deer for which ecchymosis scores were recorded at the type B abattoir which used the same stunning and exsanguination methods but with an interval between stunning and exsanguination of < 5 seconds, or the D1 abattoir which used a
percussion stunner or .22 calibre firearm followed by gash cut exsanguination no less than 25 seconds later (Table 37).

8.4.4 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 (Chapter 8, page 185) 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.
8.5 Conclusions

The mean peak current (0.79 amps, SEM± 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, compared with a stun current duration of 1 second in the current study, 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 initiate 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 used 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 either not have caused concern, or it may not have 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 stun current 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 6 cm caudal to the ears, rather than the normal position of less than 3 cm from the ears. It would appear that regardless of the peak stun current recorded, a successful stun may be contingent on the correct placement of the probes no more than 3 cm caudal to the baseline of the ears.

All of the deer unsuccessfully stunned electrically, were stunned again using a captive bolt. One deer was 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, compared 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, compared 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, in addition to these, there may also have been a number of other differences between the deer, which were 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 UWS-H farm and were all similar in weight and age. In contrast, within each of 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 UWS-H 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 which investigated 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± 0.39) at 150 volts, to 2.75 amps (SEM± 0.17) at 400 volts. As regulated 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-controlled rather than voltage-controlled devices.
The incidence of ecchymosis in the current study was considerably higher than that recorded in case studies of any mobs slaughtered at commercial type B and D1 abattoirs (Chapter 5, page 129). 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 UWS-H 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 compared with captive bolt at the type D1 abattoir. Both stunning method, and the interval between stunning and exsanguination, were investigated further in Chapter 9 (page 208).

The voltage used at the type B abattoir from which case study data was obtained (Chapter 5) 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 heart beat after stunning was shown not to have any effect on ecchymosis expression. Interestingly, of the 6 bucks for which heart beat duration was recorded, 3 recorded periods of just over 200 seconds and the other 3 recorded periods of approximately 140 seconds. This was in contrast to the maximum periods 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 ng/ml, 95.9 ng/ml, and 73.5 ng/ml, in comparison with the mean levels for lambs of 61.3 ng/ml 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 ng/ml, 21.2 ng/ml, and 21.6 ng/ml recorded for the deer, and 26.1 ng/ml 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 UWS-H abattoir (Chapter 7, page 169). 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 occur prior to the use of voltages less than 150 volts for 1 second for the head only electrical stunning of fallow deer, even at a stun duration 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 same 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.
### Chapter nine:

"Combinations of stunning and exsanguination methods"

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9.1 Introduction

By the end of the current study (1998), in addition to a number of type B abattoirs becoming available again for the slaughter of deer, a number of other abattoirs, some said to be deer specialist abattoirs (Type D2) and others built initially to slaughter ratites (Type D1) also commenced slaughtering deer. 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.

All of these abattoirs, including the existing type B abattoir which catered exclusively for the Muslim market, had acquired, or were in the process of acquiring, accreditation for export to Europe and USA, a move that reflected the diminishment of the Muslim market. This meant that the thoracic stick method of exsanguination could be adopted for the slaughter of a considerable proportion of the annual deer kill. In this respect, the thoracic stick had been shown previously to significantly reduce the incidence of ecchymosis compared with the gash cut method (Chapter 7, page 159), when incorporated in to the type B abattoirs, but this was yet to be determined for type D abattoirs. Head only electrical stunning could also be replaced by captive bolt stunning in type B abattoirs, however, not without compromising the speed and/or cost of the operation.

At the type D abattoirs, in which the intervals between stunning and exsanguination varied from 15 seconds to over a minute, adherence to convention by Muslim slaughtermen was observed to differ considerably between establishments, and deer were observed being shot with a .22 calibre rifle, penetrative captive bolt, or

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7 At the time of writing, the cost of the explosive charges for the penetrative captive bolt used in the current study was approximately 20 cents each (1 required per animal), compared with the negligible cost of electricity.
mushroom head captive bolt, apparently regardless of the destination of the carcases. Electrical stunners were installed at both type D abattoirs. However, reports indicated that due to the incompetence of the staff, with respect to the use of electrical stunning devices, deer had not been rendered insensible when it had been attempted.

By the end of 1998, the situation in the Australian venison industry was such that almost all potential methods of stunning, some of which had been shown to reduce the incidence of ecchymosis in other species of livestock (Chapter 2, page 22), could be considered for deer. In reality however, most alternative methods of stunning could be precluded on the basis of establishment costs given the economic instability of the industry, and the effect of this on capital investment in infrastructure. Of the possible alternatives, head to back stunning, which was shown to eliminate ecchymosis in some other species (Petersen et. al., 1986) could be incorporated easily into type B abattoirs. However, the method of restraint used in type D abattoirs precluded the use of this method therein. Head to back stunning was also shown to increase the incidence of the other haemorrhagic syndrome ‘speckle’ in sheep, and it would be necessary to determine whether this condition occurred or was of concern in venison. There was also potential for use of the mushroom head captive bolt*, which was observed in a type D abattoir late in the current study, however, time constraints precluded this method being investigated further.

Ultimately for the Australian venison industry, the greatest potential for the immediate reduction of the prevalence of ecchymosis was through the choice of 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.

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., 1980-81b). In an experiment comparing head only electrical stunning with captive bolt stunning prior to

* Sometimes referred to as ‘percussion stunner’.
gash cut exsanguination, Grogan (1998) also reported a significantly higher incidence of ecchymosis in the carcases of the electrically stunned fallow deer. The work of Spencer (1979), Kirton et. al. (1980-81b), 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 authors 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 previous experiments (Chapter 8, page 176), would not have caused the typical tonic phase reaction normally observed in electrically stunned fallow deer to occur.

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 carcases 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.

The first of the current experiments 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 UWS-H 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.

The second of the current experiments involved two trials which investigated the
effect of two different intervals between stunning and exsanguination on ecchymosis
incidence in does. 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 carcases of head-only electrically stunned fallow
deer bled by either gash cut or thoracic stick (Chapter 7, page 159), 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 (Chapter 7, page 169) 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 (Chapter 4, page 105) 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 'slaughter day effect' (Kirton et. al., 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 gillt's (Burson et. al., 1983), but no effect was shown between these two sex types and ecchymosis.
A further experiment in the current study 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 UWS-H abattoir were 91 ng/ml and 65 ng/ml the day before slaughter, and 106 ng/ml and 96 ng/ml at slaughter (Chapter 8, page 188). For a group of bucks also slaughtered at the UWS-H abattoir the mean cortisol level the day before slaughter was 73 ng/ml and at slaughter 74 ng/ml (Chapter 8, page 188). In a further trial (Chapter 7, page 169) conducted at the UWS-H abattoir the mean cortisol level for a group of bucks at slaughter was 84.37 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 81.27 ng/ml (Chapter 5, page 137). Within the range of circulating testosterone and cortisol levels which occurred in the deer slaughtered at the UWS-H 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 current experiments and analysed for circulating cortisol, testosterone and progesterone. As an indicator of pre-slaughter stress, ultimate carcase pH was also determined for carcases from the experiment comparing sex types. The experiments also contributed data to the determination of rates of blood loss associated with slaughter methods (Chapter 6, page 148).
9.2 The effect of stunning and exsanguination method on ecchymosis in fallow deer does

9.2.1 Introduction

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 (Chapter 7, page 159) 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 10 to 15 seconds. Further to this, the aforementioned experiments involved head only electrical stunning exclusively, 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 rest 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 or shooting with a .22 calibre rifle 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 causing 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.
Levels of circulating cortisol and testosterone concentrations from blood plasma samples collected the day before, and at slaughter from bucks and castrates slaughtered at the UWS-H abattoir were determined from previous trials (Chapter 7, page 169; Chapter 8, page 188). 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 UWS-H abattoir.

9.2.2 Materials and Methods

9.2.2.1 Animals and pre-slaughter treatment

Fallow does of mixed ages were slaughtered in two trials at the UWS-H abattoir in spring (October). The does originated from the same farm and had been held at UWS-H farm for 2 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 45.2 kgs (SEM± 0.7) for those from the first trial ($n= 23$) (trial A) and 45.4 kgs (SEM± 0.7) for those from the second trial ($n= 25$) (trial B). As previously described (Chapter 3, page 52), blood was collected from the does used in trial A the day before slaughter. The deer remained overnight in the UWS-H deer farm 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.

9.2.2.2 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).
9.2.2.3 Stunning and exsanguination techniques

Consistent with the experiments investigating exsanguination methods at the type B abattoir (Chapter 7, page 159), electrical stunning was carried out using 400 volts for a duration of 3 seconds. Captive bolt stunning and gash cut and thoracic stick methods of exsanguination were performed as previously described (Chapter 3, page 43).

At the start of trial A attempts were made to exsanguinate the first 6 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.

9.2.2.4 Measurements

The method for measuring rates of blood loss, and the results were as previously described (Chapter 6, page 152). As described in Chapter 3 (page 43), blood samples were also collected 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 carcase weight was measured just prior to chilling. Echymotic lesions exhibited were scored using the boning room grading method previously described (Chapter 3).

9.2.2.5 Statistical analysis

Carcases 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.
9.2.3 Results

9.2.3.1 Carcase weights

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

9.2.3.2 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).

9.2.3.3 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.

9.2.3.4 Circulating cortisol concentrations

The mean circulating cortisol concentrations measured from the samples taken the day prior to slaughter, and at slaughter were 72.8 ng/ml (SEM± 5.3) and 92.5 ng/ml (SEM± 4.2) respectively. When assay data for individual animals were 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 were ranked according to progesterone levels there was no relationship observed 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.

For each of the slaughter treatment groups over half of the carcases 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 38 and Table 39).

Table 38: Trial A left and right loin, round, and rump ecchymosis scores and blood loss data for does slaughtered by 4 combinations of stunning and exsanguination methods.

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<th>Captive bolt</th>
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*not pregnant

Table 39: Trial B left and right loin, round, and rump ecchymosis scores and blood loss data for does slaughtered by 4 combinations of stunning and exsanguination methods.

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* not pregnant

9.2.4 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 (Chapter 8, page 188). As
with the live weights, the carcase 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 UWS-H abattoir (Chapter 8, page 188). 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 (Chapter 7, page 159) 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., 1980-81b) 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 (70 volts) used as discussed earlier. 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 UWS-H 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 physically more predisposed 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.
9.3 The interval between stunning and the initiation of exsanguination and its effect on ecchymosis in fallow deer does

9.3.1 Introduction

Previous experiments investigated the effect of 4 slaughter treatments on the incidence of ecchymosis in fallow does slaughtered at the UWS-H abattoir. The 4 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 (Chapter 7, page 159). 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., 1980-81b), 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 UWS-H 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.
comparing short intervals of 10 to 20 seconds, with long intervals of 90 to 140 seconds. This was in contrast to intervals observed in deer slaughter systems which ranges from less than 5 seconds to greater than 10 seconds. In sheep, a long interval was observed to cause more ecchymosis than a 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 method was used to exsanguinate all the pigs. With respect to 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. At some abattoirs intervals of greater than a minute were observed.

The current experiments 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 UWS-H abattoir. Circulating progesterone concentrations were also recorded for the does. The present experiment extended further the data on cortisol and progesterone levels in does.

9.3.2 Materials and Methods

9.3.2.1 Animals and pre-slaughter treatment

Two groups of twenty two fallow does were slaughtered at the UWS-H 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 25.5 kgs (SEM± 0.5), and the second trial (trial D) 24.0 kgs (SEM± 0.4). The does had been synchronized for mating, and at the time of slaughter were at approximately 150 days (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 UWS-H 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.

9.3.2.2 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).

9.3.2.3 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 previously described (page 179), 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 (Chapter 8, page 188). Captive bolt stunning was as previously described (Chapter 3, page 58). The deer were all exsanguinated by the thoracic stick method (Chapter 3, page 54). The deer from the delayed interval treatment group were exsanguinated while recumbent after being removed from the restrainer. In attempting 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.

9.3.2.4 Measurements

As previously described (Chapter 3, page 52), blood was collected from the does in trial C at exsanguination and circulating cortisol and progesterone concentrations 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 grading method previously described (Chapter 3, page 44).

9.3.2.5 Statistical analysis

Using the total ecchymosis scores for the loins, rounds, and rumps, data were analysed using analysis of variance.

9.3.3 Results

9.3.3.1 Peak stun current

The mean peak stun current was 1.33 amps (SEM± 0.11) in trial C, and 1.39 amps (SEM± 0.07) in trial D.

9.3.3.2 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 ng/ml and 0.78 ng/ml compared with the mean progesterone level for the remainder of the does which was 5.39 ng/ml (SEM± 0.32). When individual assay data were plotted according to ecchymosis scores there was no relationship to be observed.

9.3.3.3 Circulating cortisol concentrations

The mean circulating cortisol concentration determined from the samples collected at slaughter was 73.1 ng/ml (SEM± 4.3). When assay data for individual animals were ranked according to cortisol levels no relationship between progesterone and cortisol levels were observed. When individual assay data were plotted according to ecchymosis scores there was also no relationship.
Table 40: Trial C left and right loin, round, and rump ecchymosis scores for does exsanguinated after a short or long interval from stunning by either captive bolt or electrical stunning methods.

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<td>Round</td>
<td>Rump</td>
<td>Total score</td>
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<td><strong>Long exsang. interval</strong></td>
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* not pregnant, exsang. = exsanguination.

Table 41: Trial D left and right loin, round, and rump ecchymosis scores for does exsanguinated after a short or long interval from stunning by either captive bolt or electrical stunning methods.

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<th>Captive bolt</th>
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<td>Loin</td>
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<td>Rump</td>
<td>Total score</td>
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<td><strong>Long exsang. interval</strong></td>
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* not pregnant, exsang. = exsanguination.

Analysing the data from each of the trials separately (Table 40 and Table 41), 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± 2.13) and for the short interval treatment group it was 0.10 (SEM± 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± 2.12), 3.55 (SEM± 1.57), 0.46 (SEM± 0.37), and 0.46 (SEM± 0.21) respectively.

9.3.4 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, progesterone levels and ecchymosis, or cortisol and progesterone levels.

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 UWS-H abattoir where the interval was generally around 10 seconds. The results of the current trial were consistent with the previous studies in 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 compared with animals exsanguinated after the short interval, whether stunned electrically or by captive bolt.

An explanation behind this phenomena was articulated in Chapter 4 (page 80) 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 the 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 on ecchymosis in lambs that the electrical current associated with electrical stunning may itself predispose blood vessels to rupture (Kirton et. al., 1980-81b). 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 (type B) 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 (Chapter 7, page 159). 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 a considerable number of deer would be required to determine the effect of stunning method on ecchymosis in such slaughter systems.
9.4 The effect of slaughter method on ecchymosis in fallow deer bucks, castrates, and does

9.4.1 Introduction

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 (Chapter 7, page 159), 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 (Chapter 7, page 169) 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 (Chapter 4, page 105) 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 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 carcase pH was also measured. This experiment also contributed data to the determination of rates of blood loss associated with slaughter methods (Chapter 6, page 148).

9.4.2 Materials and Methods

9.4.2.1 Animals

Twenty four does, twenty four entire bucks, and twenty four castrates were slaughtered in winter (June) at a type D2 abattoir described in Chapter 5 (page 137) 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 22.6 kgs (SEM± 0.4), the castrates 27.4 kgs (SEM± 0.5), and the bucks 27.5 kgs (SEM± 0.4). All the deer originated from the same farm except 12 of the does. The does and castrates were held at the UWS-H 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 UWS-H 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 yared 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 yared approximately 4 times over two years, and moved from paddock to paddock numerous times.

9.4.2.2 Transport and lairage

The deer were yared 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 km, and transport to the abattoir took 1.5 hours including loading and unloading. The distance from the UWS-H farm to the abattoir was approximately 150 km, which took 3 hours including loading and unloading. 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.

9.4.2.3 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 3 does from each farm source.
9.4.2.4 Stunning and exsanguination techniques

Head only electrical stunning was at 250 volts for 2 seconds using a voltage-controlled device previously described (Chapter 8, page 179). Captive bolt stunning and thoracic stick and gash cut exsanguination were as previously described (Chapter 3, page 43). Exsanguination was initiated between 15 and 20 seconds after stunning. The deer exsanguinated by the thoracic stick method were hoisted onto the dressing out rail prior to exsanguination, while the gash cut deer were bled in lateral recumbency.

9.4.2.5 Measurements

The method for measuring rates of blood loss, and the results were as previously discussed (Chapter 6, page 148). Blood samples were collected at exsanguination and circulating cortisol, progesterone and testosterone concentrations were measured as previously described (Chapter 3, page 52). The uterus of each doe was examined during evisceration procedures to determine pregnancy status. Ultimate pH was measured twenty four hours after slaughter, and carcases were graded for ecchymosis using the boning room grading method described previously (Chapter 3, pages 51 and 44).

9.4.2.6 Statistical analysis

Total loin and round ecchymosis scores were used to indicate ecchymosis incidence and severity. These data were square root transformed because of heterogeneity of variance and analysed using analysis of variance. Logistic regression was used to determine the effect of sex type on ecchymosis incidence. Relationships between sex type and cortisol, peak stun current, and ultimate pH, were analysed using analysis of variance.

9.4.3 Results

9.4.3.1 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 (p= 0.05) more ecchymosis 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 carcases 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 18).

Figure 18: The incidence of ecchymosis in deer slaughtered by 4 combinations of stunning and exsanguination methods comprising electrical and captive bolt stunning and gash cut and thoracic stick exsanguination.
Using the total loin and round ecchymosis scores, there was no sex type by slaughter treatment interaction of significance observed in the current experiment. However, when little or no ecchymosis (Grade 0 or 1) was compared with some ecchymosis (≥ 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 19).

![Bar chart showing ecchymosis in various sex types](image)

**Figure 19:** 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 between slaughter treatments and circulating progesterone, testosterone, or cortisol concentrations, or ultimate pH, reflected in the data, with respect to ecchymosis expression.

**9.4.3.2 Cortisol, testosterone, and progesterone levels**

The mean circulating testosterone concentrations for bucks and castrates were 0.59 ng/ml (SEM± .02) and 0.44 ng/ml (SEM± 0.02) respectively. The mean circulating progesterone concentration for the does was 3.97 ng/ml (SEM± 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 49.1 ng/ml (SEM± 2.7), 77.9 ng/ml (SEM± 4.7), and 74.8 ng/ml (SEM± 5.4) respectively.

9.4.3.3 Electrical stunning

The mean peak stun current for the bucks, does, and castrates combined was 1.37 amps. (SEM± 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± 0.09), and lowest for the does at 1.28 (SEM± 0.09). The mean peak stun current for the castrates was 1.37 (SEM± 0.14).

9.4.3.4 Ultimate pH

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

9.4.4 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 were consistent with those observed in a
previous trial (Chapter 9, page 222), 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 compared with electrical stunning. Reasons for this occurrence were discussed previously (Chapter 4, page 80; Chapter 9, page 222), and are most likely related to the dynamics of blood distribution, which was affected by methods of stunning in relation to the interval between stunning and exsanguination.

From previous trials (Chapter 7, page 158; Chapter 4, page 105) 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 predisposition to ecchymosis than does, and does had a greater predisposition 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 UWS-H abattoir, and samples collected from fallow deer slaughtered commercially, as discussed in the introduction (page 214). However, the mean cortisol level recorded for the bucks used in the current trial was lower than observed in any other trial. The higher ultimate pH observed in the carcasses of the bucks compared 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 reflected the results of a previous trial, in which bucks were slaughtered in the autumn period, when rutting behaviour was greatest (Chapter 7, page 169). With respect to the proposition that pre-slaughter stress predisposes 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 the bucks, compared with the castrates and does.
9.5 Conclusions

As discussed previously, 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 ratsites (Type D1), commenced slaughtering deer. In addition to this, the existing type B abattoir and others 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., 1980-81b; 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 was 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 a much larger number of animals would be needed to observe any potential effect.

When carcases from deer exsanguinated after either a short (4 - 14 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, 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 specifically, 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 to be inappropriate for the slaughter of fallow deer.

The effect of exsanguination method was also investigated, and regardless of the interval between stunning and exsanguination, or the method of stunning used, the thoracic stick method was shown to reduce ecchymosis compared with the gash cut method. This result was consistent with previous studies (Chapter 7, page 159) and clearly the thoracic stick method of exsanguination should replace the gash cut method in all fallow deer slaughter systems.

The results were consistent with observations of previous experiments (Chapter 4, page 105; Chapter 7, page 158), in which it was apparent that castrates, does, and bucks may each have a different predisposition to ecchymosis. It was shown that
castrates were more likely to be affected by ecchymosis, than does or bucks, and bucks were less likely to be affected than castrates or does. Also associated with sex type, measurements of cortisol, progesterone and testosterone were made, and as observed in previous trials, no relationship existed between levels of these hormones and ecchymosis incidence on an individual animal basis. On a sex type basis however, it was interesting to observe 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 and again a sex type effect was observed, with the highest pH levels occurring in the bucks. This was proposed to reflect physical stress prior to slaughter associated with rutting behaviour. Accordingly, it was suggested that when discussing the effect of pre-slaughter stress on ecchymosis, distinction should be made between physical stress, as manifest 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 (Chapter 7, page 169) using methods considered favourable to the production of ecchymosis, consistent with the current experiment, although pH was extremely high, very little ecchymosis occurred. 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 predispose 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 animals of 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 predisposed 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 a large number of animals. Unfortunately, attempts made during the current study to conduct experiments in commercial abattoirs where large numbers of animals were available, were largely unsuccessful due to the actions of the commercial venison processors involved (Chapter 5, page 120).
Chapter ten: Conclusions

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10.1 The economic significance of ecchymosis

The current study was initiated after significant economic losses incurred from the condemnation of venison exhibiting ecchymosis, were being passed on to deer farmers by venison traders. Anecdotal reports from processors indicated that 20% of all fallow deer slaughtered in Australia and to a lesser extent red deer were affected by ecchymosis. In some kills the incidence was reported to be as high as 100%.

In Australia, up to 34,000 deer, or 15% of the farmed deer population of 230,000 deer are slaughtered in some years, and of the venison from these deer approximately 85% is exported and thus subject to the export requirement (EMO 2.222) that meat exhibiting ecchymosis be condemned as unfit for human consumption. The proportion of fallow deer farmed in Australia is approximately 48% of the total farmed deer population (RIRDC, 1996), thus it could be expected that up to 13,870 fallow deer are slaughtered each year for export. For fallow deer carcasses of 25 kg, the expected meat yield for the hind leg primal and loins would be approximately 8 kgs (extrapolated from Mulley, 1989), which would equate to 111 tonnes of fallow deer venison hind leg primal and loins being exported from Australia each year. Conservatively, if this meat were to sell at retail for A$ 15 per kilogram this would constitute revenue of A$ 1.7 million.

Results from the current study, with respect to ecchymosis detected in commercial abattoirs and boning rooms, indicated that 3190 (23%) of the fallow deer slaughtered for export from Australia could be expected to exhibit ecchymosis in the left round, based on the inspection in the abattoir chiller of the round while still attached to the carcase. In the boning room, at least 2712 (85%) of these carcasses would then be expected to have some ecchymosis detected in each of the other hind leg primal and loins. Thus, if meat export requirements were strictly adhered to, and all ecchymotic meat was condemned, in the vicinity of 21.7 tonnes of fallow deer venison would be condemned from export each year due to ecchymosis, and this would constitute a loss of revenue of A$ 325,440 per annum to the Australian deer industry. It was observed in the current study, that often only meat exhibiting ecchymosis worse than grade 1
was condemned, or alternatively, grade 1 ecchymosis could be removed by denvering. If this were the case, the loins and other hind leg primals of only 2042 (64%) of the 3190 carcases with ecchymosis in the round, would have to be condemned, at an estimated value of A$ 245,000. It should also be noted that 7% of the Australian farmed deer population were rusa deer or chital deer, the former of which was associated with the highest recorded incidence of ecchymosis in the current study, with up to 58% of the loins from some kills exhibiting ecchymosis greater than grade 3. It was also observed that although minimal in comparison with fallow deer and rusa deer, red deer could also be affected by ecchymosis, thus making the aforementioned estimated loss of revenue conservative.
10.2 Factors associated with the prevalence of ecchymosis in fallow deer

10.2.1 Introduction

From a review of the literature, a number of factors could be postulated to be associated with the occurrence of ecchymosis in fallow deer. Factors associated with slaughter, such as stunning, exsanguination, and the means by which animals were presented for slaughter, could be manipulated immediately by human intervention, and thus were the focus of the current study. However, other factors associated with the intrinsic physiological responses of deer to slaughter activities and their affect on ecchymosis were also investigated, such as the comparative predisposition of fallow deer of three different sex types to ecchymosis, pre-slaughter stress as manifest in steroid hormone (cortisol) response, and meat quality (pH).

The anatomical distribution of ecchymosis throughout the fallow deer carcase was investigated, and implications on inspection systems for ecchymosis were discussed. The results of this study with respect to the anatomical distribution of ecchymosis also helped to explain the relationship between blood distribution at and around the time of slaughter, as influenced by stunning, exsanguination, and the interval between stunning and exsanguination, and the relationship of these factors to ecchymosis expression.

The current study also discussed aspects of quality improvement related to the Australian deer industry including; approaches to research and development, the potential for autonomous meat quality improvement in the venison processing sector, and Quality Assurance in the wider industry in general.

10.2.2 Stunning and exsanguination methods

There were a number of different slaughter systems available for the slaughter of fallow 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 (see slaughter system descriptions chapter 5, page 129).

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, which comprised a v-restraining conveyer commonly used for sheep and goats, the interval between stunning and the initiation of exsanguination was < 5 seconds. The incorporation of the thoracic stick method of exsanguination rather than the gash cut method in these slaughter systems significantly (p< 0.001) reduced the incidence of ecchymosis when combined with electrical stunning (Chapter 7, page 158), and the literature regarding other species (Chapter 2, page 18), and reports from Grogan (1998) of trials using deer, indicated that captive bolt stunning may reduce this level of ecchymosis incidence further. It was not possible to discern whether captive bolt stunning would reduce ecchymosis incidence further in these slaughter systems, because the large number of animals required to test this, due to the significant reduction of ecchymosis attributed to the thoracic stick method alone, were not available in this study.

However, in a type E abattoir which was purpose built for slaughtering deer the size of fallow deer, the interval between stunning and the initiation of exsanguination was generally < 8 seconds, making this slaughter system not too dissimilar to the type B systems. From case study data recorded on the prevalence of ecchymosis, this abattoir experienced extremely little ecchymosis using captive bolt stunning combined with the thoracic stick method of exsanguination (Chapter 5, page 141), suggesting that perhaps in type B abattoirs also, captive bolt stunning would further reduce ecchymosis expression, compared with electrical stunning.
At some type A abattoirs, the presentation of the animals for stunning was similar to type E abattoirs, but the interval between stunning and exsanguination was greater than 10 seconds. In association with this longer interval between stunning and exsanguination, the prevalence of ecchymosis was considerably greater at these type A abattoirs, compared with type E abattoirs, despite captive bolt stunning or shooting with a firearm, and thoracic stick exsanguination, being the slaughter methods used at both (Chapter 5, pages 129 and 141). This indicated that perhaps the interval between stunning and exsanguination regulated in some way the effect that stunning method would have on ecchymosis expression.

This was confirmed in a subsequent study (Chapter 9, page 222), where the effect of the interval between stunning and exsanguination on ecchymosis expression in skeletal muscles was investigated, and found to be highly significant (p< 0.008), with a short interval (mean 7.5 seconds) associated with a lower incidence of ecchymosis than a long interval (25 seconds). This occurred regardless of stunning method used, and with all deer exsanguinated using the thoracic stick method. In the same experiment, although not significant (p= 0.055), a treatment effect with respect to each of the 4 slaughter method combinations used 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. This result, with respect to stunning method, was in contrast to that which was observed in the slaughter systems with short intervals between stunning and exsanguination.

This interaction between stunning methods and the interval to exsanguination, and their combined effect on the incidence of ecchymosis, was postulated to be due to the different effects of the stunning methods, with respect to the rerouting of blood to the thoracic cavity, and the short interval to exsanguination whereby blood was lost from the vascular system almost immediately, compared with the long interval to exsanguination whereby there was sufficient time for the blood to re-circulate to the musculature and leak out of ruptured muscle blood vessels. This was particularly apparent when the distribution of ecchymosis throughout the skeletal muscles and visceral organs were compared (Chapter 4, page 80).
The investigation of slaughter methods was further extended in another study using 72
deer of three sex types, slaughtered in a type D abattoir where the interval between
stunning and the initiation of exsanguination was maintained at approximately 15
seconds, and the deer were stunned either electrically or by captive bolt, and
exsanguinated by either the thoracic stick or gash cut method (Chapter 9, page 230).
In this slaughter system as postulated, captive bolt stunning was associated with a
higher incidence of ecchymosis than electrical stunning (p< 0.05) in groups of deer
whether exsanguinated by the thoracic stick or gash cut methods. Consistent with
studies conducted in other abattoirs, where the interval between stunning and
exsanguination (< 10 seconds) was less than at the type D abattoir (15 seconds), the
thoracic stick method of exsanguination incorporated into the type D abattoir still
reduced ecchymosis compared with the gash cut method, although the effect was not
as significant (p< 0.03).

Based on the results of the current study, the most effective slaughter system for
reducing the incidence of ecchymosis in fallow deer would be the type B system,
incorporating captive bolt stunning and the thoracic method of exsanguination. In
slaughter systems where the interval between stunning and exsanguination is greater
than 10 seconds, the incidence of ecchymosis may be reduced by electrical stunning
being used rather than captive bolt stunning. This is due to the electrical stun causing
blood volume to remain in the visceral organs (as a result of the prolonged tonic
phase), for longer than occurs with captive bolt stunning, where it is lost via thoracic
stick exsanguination.

Importantly, while electrical stunning was shown to reduce ecchymosis compared
with captive bolt stunning, in type D abattoirs which had the longer interval (> 15
seconds) between stunning and exsanguination, 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 may have been
difficult to achieve in some type D abattoirs due to the design of the devices used for
restraining deer.
10.2.2.1 Rates of blood loss

Associated with the dynamics of blood loss and its effect on the incidence of ecchymosis, exsanguination method was shown to be a critical factor in attempts to reduce ecchymosis. From the results of the current study, 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. Electrical stunning was associated with a greater rate of blood loss in thoracic stuck deer, compared with captive bolt stunning being associated with the greater rate of blood loss in gash cut deer.

10.2.2.2 Electrical stunning

In the current study, 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 were conducted (Chapter 8, page 176), and it was revealed that fallow deer 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 or duration of electrical stunning affected the interval to cessation of heart beat (mean = 113.8 seconds after stunning), which was a major consideration guiding Muslim slaughter techniques (Chapter 8, page 188). Since stun voltage had no effect on duration of heart beat, down regulation of the voltage applied by Muslim slaughtermen in commercial works should be discouraged.

On the basis of reducing ecchymosis, neither voltage, current, duration, or combinations of voltage and duration were shown to effect the expression of ecchymosis in groups of deer of mixed ages, weights, and unknown pre-slaughter history. The voltages tested ranged from 150 volts to 400 volts, and the stun current duration from 1 second to 3 seconds (Chapter 8, page 188). In one study using a limited number of deer (n= 13) the duration of the stun current at 400 volts showed a significant treatment effect (p < 0.01), with a lower incidence of ecchymosis observed
in deer stunned for 3 seconds, compared with deer stunned for 1 second (Chapter 8, page 185). This was postulated to be associated with the maintenance of the tonic phase and its relationship to blood redistribution prior to exsanguination.

10.2.2.3 Restraint

Restricting the movement of fallow deer subsequent to the onset of the grand mal seizure induced by electrical stunning was tested (Chapter 4, page 105), 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 its welfare.

10.2.3 Sex type as a pre-disposing factor to ecchymosis

The effect of sex type on the expression of ecchymosis was observed in a number of experiments and tested conclusively in experiments reported in Chapter 9 (page 230). Castrates were observed to be 9.8 times more likely to have ecchymosis than bucks (p= 0.002), and does 4.2 times more likely (p= 0.06). Further to this, it was observed that bucks slaughtered during the breeding season were more likely to have bruising and lesions from traumatic injury, and high ultimate carcase pH from muscular exertion, rather than ecchymosis resulting from slaughter (Chapter 7, page 169). 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.
10.3 The anatomical distribution of ecchymosis

The development of an ecchymosis grading system was considered fundamental to guaranteeing the quality of Australian venison exported overseas. Unfortunately the only way that venison could be guaranteed ecchymosis free was by inspection and condemnation of affected meat after the boning out of carcases (Chapter 4, page 62). For those vendors wishing to export whole carcases an inspection system based on examination of the round (M. vastus lateralis) while attached to the carcase was developed, which could be incorporated into processing systems to provide some indication of ecchymosis incidence prior to boning. In developing the grading system, the presence of ecchymosis in the diaphragm or abdominal muscles, and in visceral organs such as the lungs and heart, were determined unreliable indicators of the presence of ecchymosis in other parts of the carcase.

In the current study (Chapter 4, page 62) fallow deer carcases (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. Unfortunately, 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. These muscles make up the loin, round, topside, silverside, rump, and blade.

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, if ecchymotic meat is to be condemned.
10.4 The adoption of technologies to reduce ecchymosis

This study has shown that a number of factors contribute to the expression of ecchymosis in the carcases 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 exists 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.

The methodological approach to the current study incorporated principles of the "Farmer first" paradigm, put forward as an alternative to the traditional Transfer of Technology (TOT) approach to research and development (R&D). This was in order to assess firstly, the potential for participatory research in the Australian deer industry, and secondly, the nature of the commercial sector with respect to the potential for the improvement of venison quality, and in particular the reduction of ecchymosis and the implementation of the QA program (Chapter 5, page 112).

With respect to the deer QA program, and the onus of responsibility for maintaining its integrity being based on the attitude of subscribers to the scheme, in the current study there was no autonomy shown by venison processors or vendors with respect to reducing the prevalence of ecchymosis. This was in spite of numerous sporadic reports indicating that ecchymosis was incurring significant economic losses, and the existence of organisational structures conducive to monitoring and improving quality. Despite constant attempts at collaboration with industry, generally only processors who gained financially through involvement with the current study participated in the research. As a result, while the processors that were involved gained financially, these partnerships with industry were unsustainable economically. In cases where processors were funded by industry to conduct research themselves, little benefit could be claimed to have been derived by the wider industry.
The extent to which the Australian deer industry is likely to attempt to improve the quality of the venison it produces, and more specifically reduce ecchymosis, can only really be determined with time, albeit the current study indicated the prognosis to be poor.
10.5 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 5 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 compared 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 stun 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 compared 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 3 cm caudal to the base line of the ears. The probes should point cranially and must pierce the skin. This procedure should only be attempted by persons trained in the technique.
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 carcases. Carcases 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 carcase, via the removal of the *M. tensor fasciae latae*. Where ecchymosis is detected in the left round of a carcase by this method, the carcase should not be exported whole as usually ecchymosis will be exhibited in every other hind leg primal and loin.

7. When deer carcases are further processed, venison should not be inspected until after it is denvered.

8. Further research should investigate the attitudes of deer farmers, processors, and vendors, with respect to; the development and adoption of technologies, the methods by which they wish research and development to be conducted, and the potential for the success of Quality Assurance or Improvement programs based on commercial sector autonomy.
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Factors associated with the occurrence of

Ecchymosis (Blood splash)

in Fallow deer (*Dama dama*)

David Fa’a Falepau, BAppSc (Syst. Agric.) (Hons)

A thesis submitted in fulfillment of the requirements for the
degree of Doctor of Philosophy

Faculty of Environmental Management and Agriculture
University of Western Sydney, Hawkesbury

February 1999
PLEASE NOTE

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David F. Falepau

February 28th 1999
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Publications arising from this study


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Abstract

This thesis describes experimental work conducted to define factors associated with the occurrence of ecchymosis (blood splash) in fallow deer, and discusses facets of the Australian venison processing sector with respect to its capacity to improve the quality of venison. 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) compared 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 may 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 between 4 and 14 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 ≥ grade 1, and 8.2% had ecchymosis ≥ 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 ≥ grade 3 in the loins. Of 94 red deer slaughtered at a type D abattoir, only 1 had ecchymosis ≥ 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 or duration of electrical stunning affected the interval to cessation of heart beat (mean = 113.8 seconds after stunning), which was a major consideration guiding Muslim slaughter techniques. Since stun voltage had no effect on duration of heart beat, 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 its 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 carcase 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 carcase.

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.

The notion of a participative approach to research and development to enhance the adoption of technology was tested, by attempting to conduct a number of experiments and case studies inclusive of commercial sector operators. As a measure of the attitude of the commercial sector in general, toward the autonomous improvement of venison quality, no voluntary monitoring of any meat quality attribute except for carcase weight occurred despite numerous attempts to initiate such activities in light of reports of high incidences of ecchymosis being received. Experimentation in partnership with commercial operators was economically unsustainable although it did ensure the knowledge of the research team with respect to the commercial processing sector remained current, and as a result the recommendations derived from the study were able to be implemented immediately in the venison processing sector to minimise ecchymosis. However, the prognosis with respect to the potential for improvement of the quality of Australian venison was poor.

This study has shown that a number of factors contribute to the expression of ecchymosis in the carcases 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.
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Abbreviations

amp _ ampere

AQIS Australian Quarantine Inspection Service

°C degrees Celsius

cm centimetre

CSIRO Commonwealth Scientific and Industrial Research Institute

DIAA Deer Industry Association of Australia

g gram

Hz Hertz

kg kilogram

μl microlitre

MIRINZ Meat Industry Research Institute of New Zealand

ml millilitre

mm millimetre

mm Hg millimetre of Mercury

n number of

ng/ml nanograms per millilitre

RIRDC Rural Industries Research and Development Corporation

SEM standard error of the mean

V voltage

Terminology

Stag male red deer

Hind female red deer

Buck male fallow deer

Doe female fallow deer
<table>
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<tr>
<td>Castrate</td>
<td>animal with gonads removed</td>
</tr>
<tr>
<td>cull</td>
<td>selection of aged or infertile animals for slaughter</td>
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<td>denvering</td>
<td>removal of inter-muscular fat and selvage surrounding a muscle or group of muscles which comprise a commercial cut</td>
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<td>see denvering</td>
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