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Maintaining product quality from the farm gate to the processing facility

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ABSTRACT

There is substantial evidence that pre-slaughter events (mustering and holding in yards, transport, lairage and pre-slaughter handling) have negative effects on product quality through bruising, hide damage and muscle pH. To minimise these negative effects, use of deer-specific, good stock handling procedures and appropriately designed facilities are essential. The duration of pre-slaughter events and human presence should be minimised. Yard pens should be appropriately sized, dark, quiet, and deer should be kept in familiar groups. Adherence to existing guidelines for transport, careful driving, and avoiding transport during hot weather are desirable. Showering deer upon arrival at the processing plant plus provision of water in lairage pens probably prevents dehydration. Conversely, showering under some conditions may add to stress and bruising damage in lairage. Research proposed to improve pre-slaughter handling includes taming and selection for tractable deer, definition of appropriate handling techniques and improved facility designs. Further work is also required to identify optimal practices for lairage, showering, washing and feeding.

Keywords: red deer; slaughter; pH; bruising; behaviour; hide damage.

INTRODUCTION

Pre-slaughter handling of deer commonly involves exposure to multiple stressors including physical exertion, transport, fasting, close confinement, novel environments and the presence of humans. This occurs during the sequence of events: mustering and holding in yards, transport, lairage and slaughter.

The majority of deer presented for slaughter are less than 14 months of age and are less used to routines of yarding and handling than older deer, and have often experienced events that are at least mildly aversive (ear tagging, velvet antler removal, weaning, weighing and social regrouping). These animals may have been transported at weaning and mixed on a new property with other deer in groups of up to 400 or more. Ideally, these now common farm routines should be avoided but they are the inevitable consequence of modern venison production systems.

Basic requirements to protect deer welfare have been recognised and widely adopted through formal Quality Assurance (Q.A.) programmes, that have established minimum standards and recommended best practices. It is noteworthy that the individual processing and export companies have incorporated the voluntary industry schemes into their own market-related product quality and food safety assurance programmes. The widespread promotion of best practice and sound techniques is part of the industry's venison production ethic. However, negative effects on product quality still occur in a significant percentage of the animals processed. There is a need for critical evaluation of the handling and environments the deer experience prior to slaughter. This review outlines the negative outcomes of pre-slaughter handling, then follows the sequence of events leading up to slaughter, describing research that has investigated the impact of these events on deer and discussing how stress might be minimised. The review material is derived primarily from studies of the predominant species farmed in New Zealand, red deer (*Cervus elaphus*) and red-wapiti (*Cervus elaphus* spp.) hybrids.

Background

As in other livestock, pre-slaughter handling depletes muscle glycogen reserves in deer, resulting in increased muscle pH at 24 hours post-slaughter (pH_u; Kay *et al*., 1981; MacDougall *et al*., 1979; Smith & Dobson, 1990).

Wounds, bruises and related lesions were a major cause of downgrading in a survey carried out in 1988-1989 in three New Zealand deer slaughter plants (DSPs) (Selywn & Hathaway, 1990). Subsequently a study at one DSP found that 7% of carcasses were downgraded for bruising, and seasonal effects on bruising were apparent, with a peak in October (Jago & Matthews, 1993; Jago *et al*., 1996). Bruising was negatively related to hot carcass weight and GR measurement, and varied according to the sex of the deer (Jago *et al*., 1996).

In 3856 deer killed over 40 days in 1997-1998 at one DSP, 19% of carcasses had shoulder muscles with pH_u values of at least 5.8, the level at which deleterious effects on meat quality arise (Pollard *et al*., 1999). Bruising (including minor bruises) was recorded in 19% of the hindquarters of carcasses and 5% of the forequarters. A concerning frequency of fighting was observed during lairage, and unsettled behaviour occurred in the final handling race before slaughter (17% of deer reared up on their hind legs in this race). Effects of farm of origin and transporter on the variables measured (pH_u, bruising and behaviour) indicated that improvements could be made during these phases, as well as in the DSP (Pollard *et al*., 1999). A subsequent experiment at the same DSP, comparing the physiology of paddock-shot and DSP-killed red deer, concluded that pre-slaughter handling created at least moderate stress and a high level of muscular exertion or damage (Pollard *et al*., 2002). Ecchymosis (due to ruptured blood vessels) observed in some slaughtered deer may be due to pre-slaughter stress

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(Wilson, 1999).

A further negative effect of pre-slaughter handling is recent damage to hides, which occurs frequently and is considered to occur during transport and/or lairage (Dickson, 1993; Baird & Walton, 2001). Eighty percent of skins, on average, in summer, are damaged with recent cuts and abrasions (N. Dickson, pers. comm.). Gore *et al*. (2002) found that 48 out of 60 deerskins in their study had a fresh scratch inflicted some time during the pre-slaughter period. Bruising was also evident on half of the skins, which possibly does not have detrimental effects on the leather because the bruises are removed during processing, but indicates damage that is likely to have carried through to the muscles below (Gore *et al*., 2002). The stage at which this damage occurs is as yet unknown, but recent work (Scobie, unpubl.) has shown differences between suppliers at one DSP which must have occurred between yarding on the farm of origin and unloading at the slaughter plant.

These studies consistently imply that pre-slaughter handling has negative effects through pH, bruising and skin damage. Each phase of the pre-slaughter process may reduce product quality. The following examines each phase in turn with the aim of identifying how to improve product quality.

Phase 1: Yarding on the farm of origin

The mere close proximity of handling facilities unsettles deer (Diverio *et al*., 1993; Pollard *et al*., 1998). Moving the deer into handling facilities increased heart rate, stress and muscle damage indicators, as well as unsettled behaviour following release back to pasture (Diverio *et al*., 1993; 1996; Carragher *et al*., 1997; Waas *et al*., 1999).

Mustering stags into yards reduced the distances between individual animals well below those observed at pasture, and increased the frequency of aggressive interactions (Pollard & Littlejohn, 1999). The frequency and type of aggressive activities, and effect of pen size on aggression, varied between seasons (Pollard & Littlejohn, 1996). Short-term confinement, especially in the small pens, seemed aversive, as the deer paced and made repetitive up-and-down head movements along the walls of the pen (Pollard & Littlejohn, 1996).

Darkening unfamiliar pens was thought to reduce the intimidation and apparent aversiveness of yarding, as deer in darkened pens grouped together less and showed less reaction to human presence, compared with deer in well-lit pens (Pollard & Littlejohn, 1994). Deer also showed a preference for dim lighting over bright lighting (Pollard & Littlejohn, 1995a). Sound-deadening was thought to be desirable in handling facilities, as noises from slamming doors and banging walls elevated the heart rates of deer in yards (Price *et al*., 1993).

A study on social conditions during yard confinement showed that deer in small groups stayed closer to an adjacent pen when it contained unfamiliar deer than when it was empty (Abeyesinghe & Goddard, 1998). Other studies showed that both social isolation and mixing with unfamiliar deer were aversive (based on measurements of heart rate, pacing and head movements) and that mixing led to increased aggression (Pollard *et al*., 1993; Price *et al*., 1993).

Humans were avoided during pen confinement (the deer grouping tightly in the pen at the point most distant from the human), indicating that this probably added to the aversive impact of the environment (Pollard *et al*., 1991; Pollard & Littlejohn, 1994; 1995b). Other indications that human presence was disturbing were increases in heart rates of deer approached by a person (Price *et al*., 1993), and greater stress responses seen in deer that underwent mustering into yards and drafted, compared with deer mustered into yards only (Carragher *et al*., 1997).

Mustering and yard confinement is, thus, stressful to deer but the degree of stress varies according to the specific practices used. Research indicates that, to minimise yarding stress, handlers should: use pen sizes that minimise agitation and aggression in the stock being held, minimise the time in yards, subdue lighting, minimise sound, keep deer together in familiar groups and minimise human presence. As human presence is difficult to remove completely, it would be worthwhile determining whether taming or selection can be used to improve the response of farmed deer. Anecdotal reports suggest that selecting against poor temperament, defined best as negative reactions to the routines of handling imposed on them, quickly adds to ease of yard movements, sorting and individual handling.

Further research could address whether positive experiences during yarding (e.g., feeding) can reduce the aversiveness of this environment. The ability of the handler to minimise agitation through quiet handling and responsiveness to the specific needs of the stock is likely to have a major effect on the yarding experience of the deer. Good facilities and stockmanship can result in quiet handling, no outward signs of damage and infrequent deer-to-deer conflict (Pearse, pers. obs.). Weather conditions and season also affect the responses of the deer (Pearse, pers. obs). Summary of successful designs for handling facilities and techniques for handling deer, and communication of this information within the deer industry, are desirable.

Phase 2: Loading

The effects of race width (0.5m or 1.5m), shape (straight or curved) and lighting (bright or dim) on the ease of movement of deer in yards have been studied (Grigor *et al*., 1997a). The deer entered curved or wide races more readily than straight or narrow races, and moved faster down the wide races than the narrow ones. Lighting was not found to affect the movement of the deer (Grigor *et al*., 1997a).

Deer that were held in yards overnight (with access to water) were no more settled during loading onto deer transporters and during transport than those mustered just prior to transport in an experimental situation (Grigor *et al*., 1998a). Nevertheless, casual observations have indicated that undertaken well, overnight lairage does settle deer (J. Tacon, pers. comm.). Industry welfare and Q.A. programmes now require a short-term pre-transport lairage of 2-4 hours to allow some emptying out of gut

contents prior to transport.

Providing subdued lighting (taking care to avoid creating shadows that can cause stock to balk) inside the trailer is thought to improve the ease of loading (J. Tacon, pers. com.) but this effect of subdued lighting was not observed when tested experimentally (Grigor *et al*., 1998a). Differences between simulated and commercial conditions, and the relatively small number of stock observed during experiments compared with commercial experience, could account for this disparity. Subdued lighting has become a relatively common practice in deer-yarding systems.

Loading and unloading from transporters was shown to be stressful to deer, and stress increased during each transitional phase of handling and transport (mustering into yards, loading and unloading) (Waas *et al*., 1999). Practical experience has provided guidelines on suitable structures for raceways and loading ramps for deer that have been incorporated into the deer industry quality assurance procedures. Poor handling will often result in deer piling on top of each other, resulting in bruising and hide damage. As with yarding, an appropriately designed facility and good stock handling will reduce such damage during this phase.

Phase 3: Transport

As in other farmed species, transport decreases liveweight through loss of tissue water, faeces and urine and increases levels of physiological stress indicators in deer (Waas *et al*., 1997; Grigor *et al*., 1998b). According to Weeks (2000), experimental studies on group size, stocking density, road conditions and duration of transport (Jago *et al*., 1993; Matthews *et al*., 1995; Jago *et al*., 1997; Waas *et al*., 1997; Grigor *et al*., 1998c) indicated that deer travelled well with few welfare problems, provided current guidelines (National Animal Welfare Advisory Committee and New Zealand Game Industry Board (NZ GIB)) were followed, care was taken on winding roads, and pen size allowed the animals to orient themselves to the direction of travel. However, increasing journey time increased liveweight loss (Grigor *et al*., 1998b), bruising (Jago *et al*., 1996), muscle damage indicators (Jago *et al*., 1997), cortisol (indicative of stress) and sodium concentration (indicative of dehydration; Waas *et al*., 1999). The frequency of bruising also varied between deer carriers (Jago *et al*., 1993; Pollard *et al*., 1999). Furthermore, Wilcockson (1986) drew attention to excessive wear on the soles of the feet, arising from abrasive surfaces and/or excessive movement or pushing of the deer.

An industry-wide transport accreditation and driver-training programme seeks to minimise these effects and has developed a culture of stock care and improved quality throughout the industry. The positive effects of this are evident with programmes like the venison marketing Cervena® and Zeal ™strategy linked to transport quality assurance programmes.

Concern was raised by Weeks (2000) that thermal conditions during summer transport of deer were largely unknown, and that the experimental studies on which recommendations were based may not have simulated commercial conditions adequately. Some knowledge of thermal conditions during transport was gained in a study of 15 red deer hinds transported during summer when the mean temperature at pasture was 25 ^{o}C and mean relative humidity was 60% (Matthews *et al*., 1996a). On most days, temperature and humidity inside the transport crate during transport were higher than ambient conditions, and rear pens were hotter than front pens. Individual deer varied in their responses to transport, but in general, handling and loading were associated with an increase in body temperature. A few animals showed signs of heat stress, and there were indications that spraying the pens with water might reduce body temperature in such individuals (Matthews *et al*., 1996a).

These observations indicate that to improve this phase (in terms of deer stress and muscle pH, carcass weight and bruising), transport duration should be minimised, existing guidelines should be adhered to, deer should be able to orientate to the direction of travel, careful driving is required, and measures should be taken to prevent the animals overheating (such as water sprays and avoiding travel during warm conditions).

Phase 4: Lairage

Lairage has been investigated in several studies, with mixed results. Pollard *et al*. (1999) observed frequent antagonism (on average 14 aggressive interactions per hour) during overnight lairage, with the frequency of antagonistic behaviour increasing during the night. Jago *et al*. (1993) found a greater frequency of bruising in deer held overnight than in those slaughtered around 15 minutes after arrival at the DSP, but in the latter deer there was a negative relationship between lairage time, and plasma glucose and carcass pH, suggesting recovery from the effects of transport.

Grigor *et al*. (1997b) studied transported deer subsequently held in lairage with hay, water and straw bedding, for 0, 3, 6 or 18 hours. In that study, there was an increase in antagonistic behaviour and a 5% decrease in liveweight over 18 hours' lairage, but an increase in liver glycogen and a decrease in plasma creatine kinase activity indicating recovery from transport. The lowest pH values were seen in the deer held for 6 hours. It was concluded that because behaviour was unsettled, the deer should be slaughtered as soon as possible after arriving at the plant (Grigor *et al*., 1997b). Experimental work on lairage (comparing continuous showering vs dry conditions, rubber mats vs concrete substrates, dark vs light conditions, and effects of lairage duration and group size) made similar conclusions (Matthews *et al*., 1994a; 1994b; 1996b). On the basis of physiological stress indicators and unsettled behaviour it was recommended that lairage time should be minimised, disturbance of the lairage pens should be minimised, and that a lower density (0.70 deer/ m^2) was preferable to a higher density (1.46 m^2) of deer in lairage pens (Matthews *et al*., 1994a; 1994b; 1996b). There were indications that although the deer did not rest much at all in lairage, dark, dry pens with a soft substrate were more conducive to resting than well lit, continuously-showered pens with concrete floors (Matthews *et al*., 1996b). A further study on lairage

indicated that keeping deer in a pen adjacent to other species (cattle and pigs) had an unsettling effect (Abeyesinghe *et al*., 1997).

In summary then, to minimise bruising and hide damage, lairage should be minimised. Findings suggest that some physiological recovery from transport stress may occur during this holding period, which may have beneficial effects on muscle pH, however, the optimal conditions and duration for such recovery have not been defined fully. Ample pen space, minimal disturbance, and provision of a comfortable resting substrate, food and water would be expected to promote recovery.

Phase 5. Handling immediately pre-slaughter

Bruising, skin damage and deleterious effects of stress and activity on pH can occur right up until the point of slaughter. In other livestock, stress immediately prior to slaughter produces pale, soft and exudative meat, resulting from excessively low pH (Lawrie, 1979). The incidence of this in deer has not yet been studied, however, there have been several instances when this condition has been evident (Stevenson-Barry, pers. obs.). Evidence that stress occurred in the handling race immediately prior to slaughter was seen in the 17% of deer that reared up, 7% that jumped, and 8% of deer that lay down in this area (Pollard *et al*., 1999). As with all other handling events, good handling and appropriate facilities will minimise stress at this time.

Intensive washing of the deer is often carried out as the stock move to slaughter (Pollard, pers. obs.). The effects this has on pH, bruising and skin damage (likely if the deer pile up on each other) and carcass hygiene have not been quantified. The practice is casually reported as being of concern in most DSPs with particular lines of animals, but without any common causes identified.

Captive-bolt stunning is commonly used at DSPs. Head-only electrical stunning was found to be humane in deer, provided the heads of the deer were adequately restrained (Blackmore *et al*., 1993). However, in practice, some DSPs have found that electrical stunning results in greater bloodsplash or ecchymosis, and there is a preference for using captive-bolt stunning (Stevenson-Barry, pers. obs.). Captive-bolt stunning is increasingly being avoided in other livestock due to potential carcass contamination by brain matter, of particular concern with regard to transmissible spongiform encephalopathy (Stevenson-Barry, pers. obs.). Issues regarding insensibility from captive-bolt stunning, variability in effects versus accuracy, and potential contamination, have yet to be investigated in deer.

Withdrawal of feed and water

Throughout the whole pre-slaughter process, deer have no access to feed, and their access to water varies over the course of the events and between operations. Under pasture conditions (where herbage provided up to 60% of water intake), deer drank 2-4 litres of water per day (Barrell & Topp, 1989; Alexander & Segiura, 1990). Although the rumen provides a reserve of food and water, it is unlikely that deer undergoing pre-slaughter handling manage to avoid hunger and dehydration. Deer that were subjected to a six-hour sequence comprising yarding, transport, then return to the same yards, showed elevations in blood sodium concentration indicative of dehydration, leading to the suggestion that deer required water for even short periods of handling (Wass *et al*., 1999).

The pre-slaughter handling period, assuming transport for three hours, afternoon arrival at the DSP and slaughter the following morning, would take a minimum of 18 hours, plus the holding period on the farm (possibly another 18 hours if the deer were held in the yards overnight and loaded at noon). Observations of red x wapiti hybrid bulls in lairage indicated that they lost about 80% of their gut contents in 16 hours (K. Drew, pers. comm.). Therefore, rumen reserves are likely to be low at the time of slaughter. Reducing gut contents makes the removal and disposal of the gut easier following slaughter. However, a study of cattle showed that fasting can have deleterious effects (besides hunger and weight loss) including an increase in pathogenic bacteria (Gregory *et al*., 2000).

The propensity for deer to eat and drink during pre-slaughter handling may be strongly influenced by external factors. In deer experimentally deprived of feed and water for two or 20 hours, 75% of the two-hour deprived deer, and all but one of the 20-hour group, drank during a further six-hour observation period in a pen with an unfamiliar trough. Most of the drinking occurred within two hours following the deprivation period, and it was concluded that water should be provided in lairage (Hargreaves & Matthews, 1995). A study in which feed and water were withheld from deer for either 3 or 6 hours showed no significant increase in feeding or drinking in a subsequent recovery period (Grigor *et al*., 1997c). Nevertheless, deer held in lairage with straw or hay, following three hours' transportation, started to eat within a further period of three hours (Grigor *et al*., 1997b). The common practice of showering deer upon their arrival at DSPs is likely to assist in rehydration (from licking water from their own or the coats of other deer) and cooling following transport. Nevertheless deer held in lairage with water troughs, and sprinklers operating continuously, showed elevated concentrations of sodium in their blood indicative of dehydration (Matthews *et al*., 1996b). The prolonged use of showering may cause problems with chilling of the deer, especially in winter (Matthews *et al*., 1996b).

The above indicates that dehydration and depletion of energy reserves through lack of food may occur prior to slaughter. Showering deer upon their arrival at the plant, and provision of water in lairage pens assist in rehydrating the deer. Effective showering techniques for cooling and rehydration, and effects of weather conditions on this, need to be identified. The desirability of fasting deer for many hours prior to slaughter, in terms of meat quality and carcass hygiene, deserves evaluation. Provision of electrolytes may be feasible, and this treatment appeared to improve carcass yield and reduce a stress-related elevation in temperature in farmed wapiti (Renecker *et al*., 1995).

Mobile slaughter

To optimise product quality, the usual phases prior to

processing could be short-circuited by killing the deer on the farm after minimal yarding. In the early days of the deer industry, a mobile slaughter plant was used (Yerex, 1979) but proved economically impractical (Seamer, 1986). More recently, mobile plants for deer have operated in Canada (Diversified Animal Management, 1997), the UK (Anon, 1993) and several plants are in use for reindeer slaughter in Sweden (E. Wiklund, pers. comm.). It would be worthwhile investigating the current economic, logistic and product outcomes of killing the deer at their farm source.

CONCLUSIONS

Current pre-slaughter handling events have negative effects on product quality through bruising, skin damage and muscle pH. Appropriate handling techniques and facilities will reduce these negative effects, and improvements may occur if the duration of each phase is minimised. Research that may assist the deer industry in improving pre-slaughter handling includes developing techniques for and assessing outcomes of taming and selection for tractable deer, definition of appropriate handling techniques and facility designs, and identification of optimal practices for lairage, showering, washing and feeding. Alternatively, the industry may consider investigating the outcomes of on-farm slaughter.

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