Preslaughter handling of Red Deer : Implications for welfare and carcass quality

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INTRODUCTION

Returns from the sale of venison constitute a major part of income from the New Zealand deer industry. In 1992, 392,000 deer were slaughtered for venison and with declining returns for velvet this number is expected to increase in 1993. In New Zealand, deer are transported from farms to licensed deer slaughter premises (DSP's) for slaughter, inspection and processing. The process of preslaughter handling involves three distinct stages: on farm; in transit; at the DSP. During each of these stages deer are exposed to a multitude of potentially stressful factors that may contribute to reduced welfare and impaired carcass quality.

On farm animals are yarded and loaded onto a transportation vehicle. The design and state of repair of the handling facilities, the prior handling experience, and the skill of the stock handler are factors which either enhance or reduce ease of movement and subsequent level of excitement and stress in the animal. Well designed yarding and loading facilities enable animals to be moved quickly and efficiently with minimal disruption, agitation and stress (Grandin, 1980).

Transportation introduces new stressors including negotiating an inclined loading ramp, close confinement with conspecifics, the movement of the vehicle, temperature fluctuations, and withdrawal from water and nutrients. Much research has been carried out to find optimal loading facilities (Lapworth, 1990), and the effect of space allowance (Tarrant, 1988), temperature (Fischer *et al.*, 1980), and fasting (Schaefer *et al.*, 1988) on behaviour, carcass and meat quality in cattle. However, there are few published studies available that provide this information for deer. Current recommendations for transporting deer are based on circumstantial evidence and the experience of transport company operators.

Once at the DSP animals are subjected to a novel environment with foreign odours, animals, noise and stock handlers. The purpose of lairage is threefold: to allow animals to rest and recover from transportation; to allow ante-mortem veterinary inspection; and to ensure minimal disruption of the slaughter schedule. MAF regulations require that deer be slaughtered within 24 hours of arrival at the DSP. It is not uncommon for deer to be held overnight in lairage before slaughter the next day. The extent to which deer are able to "rest" while in lairage is unknown as no observations of behaviour during lairage have been made. In cattle resting behaviour is influenced by human activity, origin of the animals, group composition, and time of the day (Cockram, 1990).

The consequences of poor handling prior to slaughter can be carcass damage in the form of wounds and bruising (McCausland *et al.*, 1982), or less visible defects in meat quality such as reduced tenderness, flavour, and shelf-life. In a survey of three New Zealand DSP's Selwyn and Hathaway (1990) found that wounds and bruising occurred in 1.34 - 9.84% of all carcasses inspected. This carcass damage is costly to both the producer and processor. The farmers are paid at a lower rate for downgraded carcasses, and the carcass weight is reduced by the trimming of bruised tissue. Trimming of bruised or damaged tissue results in increased processing time and costs.

In addition to physical defects, aspects of preslaughter handling may put the welfare of the animals at risk. Welfare is regarded as ideal when the physical and behavioural needs of the animals have been met. That is, when animals are free from: hunger and thirst; physical discomfort and pain; injury and disease; fear and distress; and are free to show important behaviours (such as social contact with other animals) and to exercise (Matthews *et al.*, 1992). During preslaughter handling there is the potential for each of these freedoms to be threatened. With appropriate handling and suitably designed handling facilities the extent to which the welfare of the animals is impaired can be kept to a minmum.

As part of a broad research project which aims to determine the stresses imposed by different handling procedures and develop alternative techniques, three studies have recently been carried out, each investigating different aspects of the preslaughter handling process.

1. Analysis of slaughter house records

This study involved an analysis of records for all animals processed at one New Zealand DSP in 1991, relating the carcasses downgraded because of bruising to factors with the potential to influence bruising levels. From 21444 animals slaughtered and processed at the DSP data were obtained including farm of origin, carrier company, distance transported, time in lairage, carcass GR (tissue depth over the 12th rib), hot carcass weight (HCW), sex and grade. For carcasses downgraded because of wounds or bruises the location of the damage was recorded (ie. hindquarter, middle, or forequarter). The distance transported was estimated based on the location of the farm. Although no information was available to allow calculation of time in lairage, it was possible to identify those animals held overnight before slaughter. Deer were therefore classed as either slaughtered on the same day as delivery, or slaughtered the day after delivery.

RESULTS AND DISCUSSION

Seasonal Factors

Over the 12 month period 6.9% of carcasses were downgraded because of wounds or bruising. Figure 1 shows the percentage of male and female carcasses downgraded in each slaughter month. For stags the monthly figure ranged from 1.2% in January to 14.3% in October, and for hinds from 2.1% in February to 13.6% in October. There was a significant association between the incidence of bruising and the month of slaughter ($p<0.001$; $\chi^2=452.4$; df=1; C=0.145; Cramer Coefficient test). Overall males had a slightly higher incidence of bruising (7.5%) than females (6.1%) but this difference was not significant. Within several months, notably April, May, June and September, there was considerable difference in bruising levels for males and females, however these differences were not consistent from month to month. The majority of bruising (78.0%) was found on the hindquarters of the carcass.

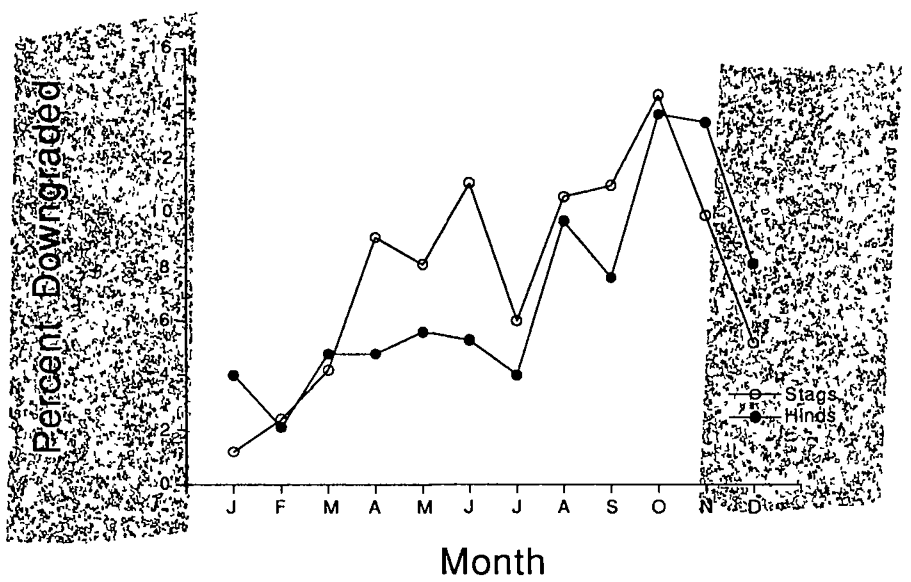

Figure 1. Percentage of male and female carcasses downgraded because of wounds or bruises according to month of slaughter.

The variable nature of monthly bruising proportions may be due to the seasonality of body composition, behaviour and stock selling patterns. Deer, especially stags, undergo immense physiological, physical and behavioural changes throughout the year. For example, during the mating season or "rut" stags drastically reduce their food intake and consequently fat levels decline, their behaviour becomes more aggressive and unpredictable. For this reason the number of stags slaughtered decreased from early March to late July. Those stags that were slaughtered during the rut had higher levels of bruising than hinds slaughtered in the same months, supporting many farmers decision not to slaughter stags during this period.

October had by far the highest incidence of bruising. The bruising rate was equally high for females and males, suggesting that velvetting, or its imminent occurrence, is not related causally to the incidence of bruising. The elevated bruising level maybe a result of some physiological and associated behavioural change common to males and females. It is also the month that two-year old venison stags are sent off before there is any risk of becoming overfat or exceeding the upper GR limit for premium grade. The much lower proportion of bruised animals in January and February may be a result of the improved physical condition of the deer at this time of the year.

Transport Factors

One carrier company (carrier 3) transported 54.9% of the deer processed at the DSP in 1991 (Table 1). Carrier company was strongly associated with the proportion of animals that were bruised in each trip ($p<0.001$; $\chi^2=109.197$; $df=10$; $C=0.842$). Differences in bruising proportions between carrier companies could be due to differences in the design of vehicles, stocking density, driving techniques and road conditions. Generally the same carrier transported animals from the same farms, therefore bruising figures for carrier companies may reflect the physical and psychological condition and treatment of deer on particular farms, especially in cases where the transporter carried deer from only a few farms.

Table 1. Distribution of animals carried by transport companies to the DSP, and the percentage of animals downgraded due to bruising (Mean ± SEM).

Carrier	No. Lots	No. Animals	Lot Size	% Bruised
1	16	349	22	15.3 (7.8)
2	10	234	23	5.0 (3.0)
3	577	11770	20	6.4 (0.9)
4	315	3707	12	8.1 (1.9)
5	23	493	21	9.3 (5.3)
6	59	581	9	7.3 (2.6)
7	8	212	27	4.5 (3.7)
8	25	540	22	4.3 (3.4)
9	27	676	25	6.3 (3.0)
10	10	680	68	8.9 (5.1)
Unknown	78	1836	23	9.1 (3.3)

The distances deer were transported from the farm to the DSP ranged from 24km to 434km. The median distance travelled was 72km. Bruising varied from 6.5% amongst deer transported less than 50km to 11.2% amongst deer transported over more than 200km (Figure 2). There was a significant association between the proportion of carcasses bruised and the distance over which the animals had been transported to the DSP ($p<0.001$; $\chi^2=31.754$; df=5; C=0.343). During transportation animals may become fatigued and as a result their ability to respond to vehicle movements may be reduced, making them more susceptible to injury, particularly bruising (Leach, 1982).

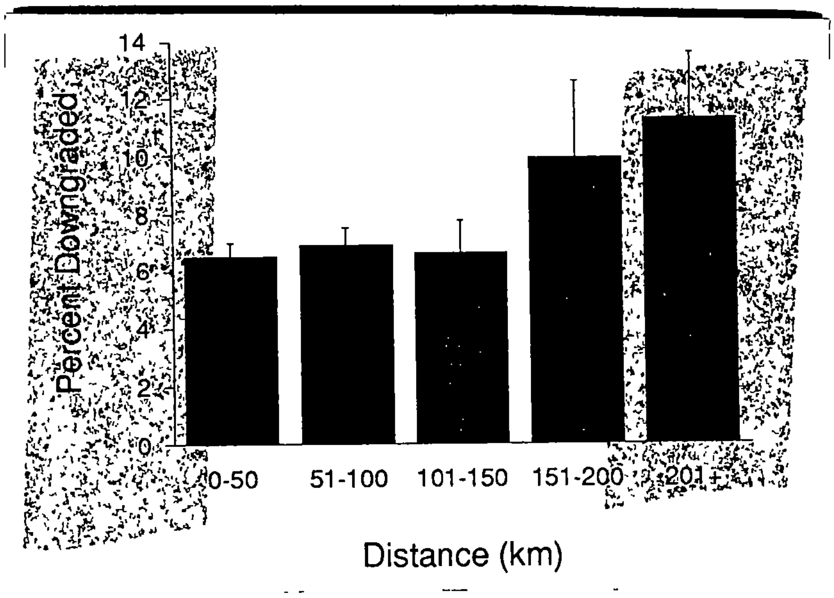

Figure 2. Percentage of animals downgraded due to bruising, according to distance transported.

Lairage
Fifty percent of animals were slaughtered on the day of arrival at the plant, the remainder were held overnight and slaughtered within 24 hours of arrival. Overall the level of bruising in animals held overnight (7.16%) was not significantly different from that for deer slaughtered on the day of arrival (6.57%). However, when separated according to month of slaughter, overnight lairage resulted in significantly higher ($p<0.05$) bruising levels in three of the twelve months. September (7.7% downgraded for those slaughtered on day of arrival, 11.9% for those held overnight), October (12.8% , 17.4%) and December (4.1%, 7.3%). The fact that duration of lairage had a significant effect on bruising levels in certain months may be due to seasonal factors such as behaviour and physical composition of the deer, however this is not clear.

Animal factors
GR was strongly associated with the proportion of animals bruised ($p<0.001$; $\chi^2=87.583$; df=7; C=0.1221). Figure 3 shows that animals with a lower GR were more likely to be downgraded because of bruising.

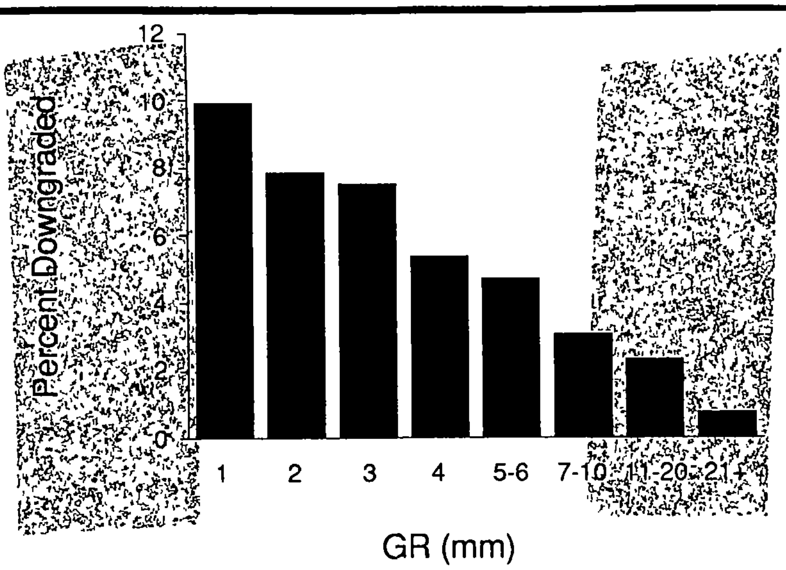

Figure 3. Distribution of animals downgraded due to bruising, as a function of GR.

It would be expected that impacts received by animals with a substantial fat cover would result in less bruising to the muscle beneath, than if the fat cover was minimal. The higher the GR the greater the fat cover. This raises a problem as fat animals are economically undesirable to the farmer, while very lean deer appear to be more susceptible to bruising resulting in downgrading of the carcass.

HCW also influenced the level of bruising, but to a lesser degree than GR. As HCW increased the proportion of carcasses downgraded decreased ($p<0.001$; $\chi^2=40.484$; df=8; C=0.0753). It seems that fat cover is of more significance than HCW in influencing the level of bruising within a lot of deer.

The results from this study suggest that physical composition of the animal, carrier company, distance transported to the DSP, and season are important factors affecting the incidence of downgrading through damage to carcasses.

2. The effect of density and road conditions on behaviour during transport

Studies with cattle have shown that loading density is the most important factor influencing their welfare during transport and subsequent carcass quality (Tarrant *et al.*, 1988). High animal densities are associated with a greater stress response and bruise score, and higher incidence of losses of balance. There are no such studies with deer.

For deer, the recommended stocking density during transport is between 0.4 and 0.5m²/100kg animal. The present study used 90kg two-year-old stags. They were transported at two densities. One (0.49m²/animal) which is at the lower end of commercial practice, and the second at 0.74m²/animal. This second density is half that of commercial practice, but was chosen to allow studies on the animals unrestricted preferred orientation during transport. The overall aim of the study was to determine the influence of loading density on behaviour when animals were transported over winding or straight roads.

MATERIALS AND METHODS

Twelve 16-month-old de-antlered red deer stags from the Ruakura herd were allocated randomly to two groups. The average weights were 86.4kg for group 1 and 92.0kg for group 2. Each group was transported on three separate occasions at each of two densities. Animals were removed from pasture immediately prior to trucking, individually raddled for identification and loaded onto the truck. The density used for each group on each journey is shown in Table 2.

Table 2. The density and order of journeys for each group.

	Density (m²/animal)		
Journey	1	2	3
Group 1	0.74	0.74	0.49
Group 2	0.49	0.49	0.74

Only one group was transported at a time, but for a given journey (1, 2 or 3) both groups were transported on the same day. Journeys were undertaken at weekly intervals.

The rear pen of a two-pen, 4.8m long transport crate was used. Density was altered by maintaining group size at 6 and varying the pen dimensions. The pen size was 1.4m x 2.1m (crate width) for the higher stocking density (0.49m²/animal). and 2.1m x 2.1m for the lower density (0.74m²/animal). The pen height was 1.83m. Ventilation slots of 9.5cm and 10.0cm were located 1.59m above the floor and ran the length of the side walls. The floor of the pen was made of 2cm x 2cm steel grating.

A video camera was mounted centrally in the ceiling of the pen and activity in the pen was recorded for the duration of each journey.

The same route was used for each journey. The journey incorporated a section of flat, relatively straight road (11 curves) and a winding, hilly section incorporating 27 curves. Each section took 10min to travel and was repeated twice per journey in the order (straight, winding, straight, winding).

The behaviour of the animals while travelling through each road type was analysed. Every 30sec the orientation of the animals was scored into one of eight categories (parallel or perpendicular to the direction of travel or one of the four diagonals). In addition, every instance of agonistic behaviour (e.g. butting, biting, kicking, boxing), every adjustment to footing to maintain balance (judged from shoulder or rump movements), and every impact with the crate walls or other animals (judged from uncontrolled movement of the animal through a distance of about 30cm prior to impact) was recorded for each animal. Further, the durations of the following activities for each animal were calculated: standing, lying, walking, jumping (forelegs off the floor).

RESULTS

The data are presented as the averages across journeys and groups for each stocking rate. At both densities on both straight and winding roads the deer spent 99.0% of the journey standing stationary. For the remaining time the deer were walking or rising up on their hind legs.

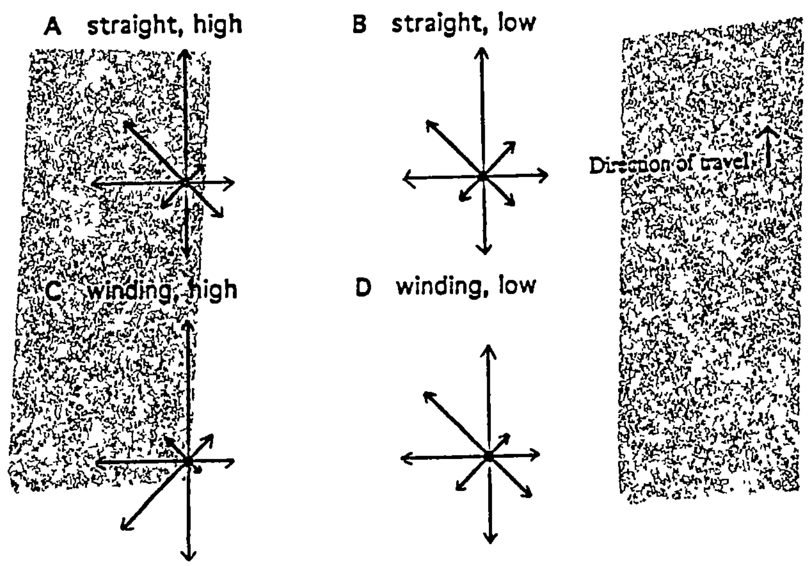

Figure 4. Percentage of time (represented by line length) spent in each of eight orientations on straight and winding roads at each of two densities, high ($0.49m^2$/animal) and low ($0.74m^2$/animal).

Agonistic Behaviour

There were relatively few agonistic interactions between the animals (23 in total over the four hours of observations on the six journeys). The agonistic behaviours were either butting or biting. There was a tendency for most of the interactions to occur at the low stocking density ($0.74m^2$/animal) on both straight (6 interactions for low density vs 1 interaction for high density) and winding (13 for low vs 3 for high) road sections. Nearly three quarters of all interactions took place on the winding road.

Orientation
The percentage of time spent in each orientation for each density on each road type is shown in Figure 4. The most common orientation at both densities and on both road types was parallel to and facing the direction of travel. Over all journeys, 23% of the time was spent in this orientation. Other common orientations were perpendicular to the direction of travel (left facing only, 16% overall) and facing the rear of the vehicle (15% overall). The deer appeared to avoid facing toward the right (overall mean of the three right facing orientations was 8%).

The time spent in the various orientations was similar for deer at both densities on straight roads (Kendall's tau coefficient, $\tau = 2.47$, $p < 0.05$) but dissimilar on winding roads ($\tau = 1.48$, $p > 0.05$). Animals spent more time orientated SW (given North is the direction of travel) at high stocking densities ($0.49m^2$/animal) on winding roads but more time orientated NW at low densities.

Loss of balance
The deer made numerous small adjustments to their footing, apparently in attempts to prevent loss of balance. The frequency of these adjustments for each road type and density are shown in Table 3. This table also shows the frequency of impacts between deer or with the pen walls.

Table 3. The frequency of adjustments to footing and collisions at each density for each road type.

	ROAD TYPE			
	Straight		Winding	
Densities	high	low	high	low
Adjustments (n)	477	420	796	688
Collisions (n)	3	3	19	10

On average, adjustments occurred at a rate of about 1/min on straight roads and 2/min on winding roads. The rate of occurrence of impacts was very low (overall mean of nine for each hour of travel). Most of the impacts occurred on the winding road sections (29/35), and there was a tendency for a higher incidence at the higher stocking rate.

DISCUSSION
At both densities the overall impression was that the animals travelled well. There were few agonistic encounters and the deer remained standing inactive most of the time. There was a suggestion of lower rates of agonistic interactions at the higher stocking density. Similar

reductions in aggressive behaviour have been observed in other animals at high stocking rates (Syme and Syme, 1979). The incidence of agonistic behaviour was higher on winding road sections. On these types of road the higher rate of loss of footing is likely to impair the ability of subordinate animals to avoid the individual space of more dominant deer leading to increased aggression.

There were many minor adjustments to footing which appeared to be necessary in order to maintain balance. Most adjustments were made with ease since few collisions with walls or other animals were seen. The frequency of collisions was higher on winding roads which probably reflects loss of balance as the vehicle travelled around sharp corners. However, it is clear that the risk of loss of balance was slight since collisions while going around curves occurred on about 1% of occasions.

The frequency of adjustments to footing was similar for both densities on winding roads. The higher numbers of collisions at the higher density probably reflects the closer proximity of walls and other animals rather than any inherent difficulty in maintaining footing.

As has been reported in studies with cattle (Kenny and Tarrant, 1987), deer prefer to align themselves parallel or perpendicular to the direction of travel. Diagonal orientations tended to be avoided as has also been noted with cattle (Kenny and Tarrant, 1987). The animals consistently avoided orientations toward the right side of the vehicle. Aspects of the pen construction are unlikely to account for this behaviour since the left and right sides were similar. Perhaps the animals were avoiding the side closest to passing traffic.

Typically, deer are transported at higher densities than those investigated here. The consequences of such densities on preferred orientation of travel and ability to maintain footing will be examined in future studies.

3. The effect of pre-slaughter handling on behaviour, blood composition and carcass muscle pH of red deer

The survey of DSP records described earlier included no information about how the deer were handled at the DSP, except whether they were slaughtered on the day of arrival or held in lairage overnight. Detailed study of cattle at a slaughter plant has shown physiological indicators of stress and muscle damage to be affected by both the behaviour of the animal and the way it is handled immediately prior to slaughter (Cockram and Corley, 1991). An understanding of these factors may be particularly important in accounting for variation in experiments which relate physiological measures at slaughter to stressors to which deer are subjected before arrival at the DSP (Smith and Dobson, 1990). For this reason, a study of deer slaughtered under commercial conditions was undertaken in order to investigate the effects of pre-slaughter handling on behaviour and physiological indicators of stress.

MATERIALS AND METHODS

This study was conducted from mid-October to mid-December 1992 and involved groups of deer slaughtered at the DSP surveyed previously. The deer were treated according to the normal routine of the DSP, that is, upon arrival they were transferred to a pen as either a single lot or, in the case of larger lots, in a group of up to 12 animals. Shortly before slaughter, the deer were moved as a group into a central holding area. From here they were transferred either individually or as a group into a single-file race. The deer were then successively moved along the race and into the stunning box. There they were stunned with a captive bolt pistol, electrically stimulated and bled out.

The data collected for each deer included: the time spent on the truck; the time spent in the lairage pen; the time taken to move the group from the pen to the holding area; the time spent in the race; the time spent in the stunning box prior to stunning; the interval between stunning and electrical stimulation; the interval between the onset of electrical stimulation and exsanguination. Scores were assigned to: the method by which the deer was handled in the race (1 = yardman walked behind the deer in the race; 2 = yardman walked along a platform on the outside of the race); the use of the electric goad (1= not used; 2 = 1 - 4 times; 3 = more than 4 times); the struggling behaviour of the deer in the race (1 = quiet; 2 = kicking the side of the race; 3 = rearing in the race; 4 = rearing and turning around in the race); the struggling behaviour of the deer in the stunning box (1 = quiet; 2 = pushing back against the rear of the box; 3 = scrambling - rapid movement of 2 or more legs; 4 = kicking back of box; 5 = sitting/lying). Blood samples were collected at exsanguination. These were assayed for plasma glucose, free fatty acids (FFA) and creatine kinase (CK). pH was determined on the neck (m. splenius) muscle 20 hours after slaughter (boning and packing procedures at the DSP precluded the collection of pH_{24} readings). Carcass information normally recorded by the DSP was also collected (HCW, GR, grade, bruise site).

To minimize variation between groups, only red deer stags transported by the company which most frequently delivered to the plant (Carrier 3, Table 1) were included in the study. For practical reasons, the investigation was restricted to deer which were slaughtered on the day of arrival at the DSP.

RESULTS AND DISCUSSION

Data were collected for 11 lots of deer. The average lot size was 13.9 and the range was 8-22, resulting in a total of 153 animals. Mean values for time spent in the successive stages of handling, physiological measures, HCW and GR are shown in Table 4. Carcass weights are similar to those reported for this time of year in the earlier survey. Similarly, CK activity was within the range previously reported in farmed red deer after transport or handling (Brelurut, 1991), although the distribution was considerably skewed (range 84-3036 U/l) and the data were subjected to a logarithmic transformation for further analysis. The pH of the neck muscle was somewhat lower than that reported by Kay *et al.* (1981).

Ten of the 153 stags (6.5%) were downgraded due to bruising. Similar rates of bruising were recorded in the 1991 survey for the same months and transport company. CK activity was higher in stags which were subsequently downgraded because of bruising than in those that were not downgraded (1013.3 $\pm$ 316.3 vs 410.3 $\pm$ 26.9; $p<0.05$) and this is consistent with muscle damage. Furthermore, CK activity was negatively correlated with GR ($r = -0.165$, $n = 152$, $p<0.05$), providing additional evidence that deer with more fat cover are less vulnerable to muscle damage. Behaviour scores, or the way they were handled immediately prior to slaughter, were similar for animals downgraded and those not downgraded. However, as downgrading is based on both the extent and the location of bruising, factors prior to slaughter which cause bruising to low-value cuts would not be detected in the analysis.

Table 4: Time spent in successive stages of handling, physiological measures, HCW and GR (mean ± SEM).

Measurement	n	Mean ± SEM
Period on truck (min)	143	90.2 ± 4.3
Period in pen (min)	153	145.7± 6.6
Time to move out of pen(s)	137	60.8 ± 4.3
Period in holding pen (min)	146	16.3 ± 1.9
Period in race(s)	150	297.5 ± 50.3
Period in stunning box (min)	152	2.0 ± 0.2
Stun to electrical stimulation interval (s)	152	37.7 ± 1.2
Electrical stimulation to exsanguination interval (s)	152	72.6 ± 1.8
pH	85	5.65 ± 0.02
HCW(kg)	153	57.7 ± 0.6
GR (mm)	153	3.7 ± 0.1
glucose (mg/dl)	152	215.3 ± 3.1
CK (U/l)	152	446.0 ± 33.0
FFA (mEq/l)	152	0.557 ± 0.020

The median score for struggling was 0 (0, 0; 25th and 75th percentiles) in the race and 0 (0, 2) in the box. Most of the deer (73%) were moved along the race by the yardman walking behind them. Sixty-four % of the deer were handled without the use of the electric goad, 27% were contacted 1-4 times with the goad and 9% were contacted more than 4 times. Although it is not possible to define causality, the method of handling in the race was significantly related to the use of the electric goad and the type of struggling in the race. When deer were moved through the race by the yardman walking behind them, they had lower struggling scores in the race ($p<0.05$, $\chi^2=6.63$, df=1; Kruskal-Wallis test) and the electric goad was used less ($p<0.001$; $\chi^2=52.17$, df=1). In addition, deer spent less time in the race if walked through by the yardman (142.5 sec vs. 709.5 sec; $p<0.001$) and had lower plasma CK activity at slaughter (401.8 vs. 568.8; $p<0.01$). In addition, the time spent in the race was inversely related to plasma CK levels at slaughter ($r=-0.265$, n=149, $p<0.01$). It is not clear whether the yardman's decision as to how to handle the deer was due to some earlier indication of intractability or whether it was based on convenience, with behavioural differences then arising because of the protracted period spent in the race when handled from outside.

There was a negative correlation between the time spent in the lairage pen and plasma glucose ($r=-0.303$, n=152, $p<0.001$), FFA ($r=-0.207$, n=152, $p<0.05$) and carcass pH ($r=-0.2647$, n=85, $p<0.05$), thereby supporting the role of lairage as a time when animals recover from the rigours of transport (Moss and Robb, 1978). It is not clear whether these relationships would be sustained in deer subjected to overnight lairage. It should also be noted that the function of lairage as a "recovery" period is likely to depend on the stressfulness of the prior handling (including transport, disruption of the social group and introduction to a novel environment).

SUMMARY

The period of handling prior to slaughter, including on the farm, during transport and at the DSP, has important implications for welfare and carcass quality. A number of factors associated with carcass damage have been identified. Animal factors such as GR and HCW may not be easily manipulated while transport and lairage factors may be easier to alter in attempting to reduce the proportion of carcasses damaged.

Two factors (density and road type) that influence welfare and bruising during transport were investigated. Deer travelled well at both densities but with more risk of impacts and aggression on winding roads and more risk of aggression at lighter loading densities. The most common orientation at both densities and road types was parallel to and facing the direction of travel.

Several physiological indicators of stress and muscle damage were identified. These were found to be related to both the behaviour of the animal and the way it was handled immediately prior to slaughter.

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