The effect of distance transported on behaviour, physiology and carcass quality of farmed red deer *(Cervus elaphus)*

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ABSTRACT

Nine groups of six hinds were transported a range of distances (80, 230 or 380km) that were representative of current commercial practice. Behaviour during transport was recorded, blood samples were collected pre and post transport and the carcasses were assessed for bruising. Losses of balance, the number of impacts and movements by animals were greatest at the start of the journey and on the steep, winding roads. Agonistic behaviour was initiated by the heavier animals and directed at the lighter animals. Bruising on the hindleg and vertebrae increased with increasing distance transported. Preslaughter handling (including transport) resulted in an increase in creatine kinase (CK), aspartate aminotransferase (AST), glucose, lactate, cortisol, total lactate dehydrogenase (LDH), LDH3, LDH4, LDH5 and a decrease in magnesium. Distance caused a further proportionate increase in plasma CK, total LDH, LDH5 and LDH4. This study suggests that bruising can be reduced and welfare improved by careful driving at vulnerable stages of the journey and grouping animals of similar weights.

INTRODUCTION

The period of intense handling prior to slaughter is often stressful and a time when animal welfare is at risk. This may result in reduced carcass quality and poor meat quality. The results of an earlier survey found that at one North Island DSP 6.5% of the 21454 carcasses processed in one year were downgraded because of recent wounds and bruises (Jago, 1994). Other surveys have reported the incidence of wounds and bruises on commercially processed deer carcasses to be between 1.34% and 9.84% (Selwyn and Hathaway, 1990, 1992). This represents a considerable economic loss to the industry and also an animal welfare concern. There is little information to identify the precise stage of pre-slaughter handling (on-farm, in-transit, at the DSP) that animals become injured. However, the large variation in bruising levels between deer transported by different carrier companies, the increasing bruising rate with distance transported, and the lack of a consistent association between time in lairage and downgrading due to bruising indicates that some of the damage occurs in transit (Jago et al., 1993).

Although our studies have indicated that there is an association between severity of bruising and distance travelled, this was confounded with transport operators (Jago, 1994). The present study aimed to determine the effect of distance transported on bruising levels when factors other than distance transported were held constant. Additional objectives were to quantify behaviour of deer and measures of stress during transport and relate these to any damage that might be seen.

METHOD

Animals

Fifty-four mixed age red deer hinds located at the Ruakura Deer Unit were randomly allocated to one of nine treatment groups and balanced according to estimated liveweight and condition score. At least four days before transportation each group of six hinds were separated from the main herd which had been formed several months previously, and held in a paddock close to the Deer Unit yards.

Procedure

Groups of six hinds were transported either 80 (short), 230 (medium) or 380 km (long). One hour before departure each group was brought into the Deer Unit yards and held in a holding pen. Each animal was individually restrained in a pneumatic deer crush while an identification number was sprayed onto its back, and one 10 ml blood sample was collected by jugular venipuncture. The animals were released from the crush and kept as a group in a holding pen. Ten minutes before departure they were loaded onto the deer transport crate. Departure times were selected to ensure that animals travelling different distances arrived and were slaughtered at the DSP at a similar time of the day.

The rear pen of a 4.8m long transport crate was used to transport the deer. The pen size was 2.1m (crate width) by 1.2m with a wooden ceiling 1.8m above the floor. Ventilation slots 9.5 cm and 10.0 cm wide were located 1.6m above the floor and ran the length of the side walls. The floor of the pen was constructed from 20 mm x 20 mm steel grating. The hinds were loaded at a density of $0.42m^2$/animal. This density is similar to that recommended by deer operators standards. A camera was mounted centrally in the ceiling of the pen so that the activity of the animals in the pen could be recorded for the duration of each journey.

A route was chosen that was repeatable, ended at a slaughter plant and consisted of both straight, flat sections of road and a steep winding section (hill). The route is shown in Figure 1. Each trip began at The Ruakura Deer Unit (Point A) and ended at Summit Deer Products Slaughter Plant on the Kaimai Range, Tauranga (Point D). The short journey length was 80 km and was a direct trip from Point A to Point D. The medium journey length was 230 km. On these journeys the truck turned in the driveway of the DSP and then drove back to the Hamilton City (Hillcrest round-a-bout, Point B), at which point it returned to the DSP (Point D). The long journey was 380 km long and included a second return trip to Hamilton City and back to the DSP.

Each group was unloaded by DSP staff and held in a lairage pen for the minimum possible time before slaughter (49 ± 3 minutes). Animals were individually walked up the race to the stunning box where they were stunned with a captive-bolt pistol. Two 5 ml blood samples were immediately collected by venepuncture from the left jugular. The animal was electrically stimulated and bled out.

Carcasses were hoisted onto a rail and had the head, distal joints, hide and gut removed. After examination of the gut contents and carcass each carcass was visually inspected for damage which was recorded by the experimenter. Bruises were classified as A, B, C or D bruises according to surface area and depth (Table 1). A carcass bruise score was therefore calculated by summing the assigned values for all A, B, C and D bruises on a carcass. To obtain an average bruise score for carcasses in a treatment group, the mean score was calculated from the individual scores.

Table 1. Criteria for classifying bruises by depth and surface area, assigned value in brackets.

	Surface area	
Depth	$\leq 9\ cm^2$	$> 9\ cm^2$
Surface	A (1)	B (2)
Muscle	C (3)	D (4)

Muscle pH was determined on the right side of the neck (*Musculus splenius*) and the right hindleg (*M. semimembranosus*) approximately 22 hours after slaughter. Technical limitations prevented a measurement being made at 24 hours post-slaughter. Hot carcass weight (HCW) (kg), GR (mm) and grade was obtained for each carcass from the DSP records.

Blood analysis
Plasma creatine kinase (CK), aspartate aminotransferase (AST), calcium (Ca), magnesium (Mg), glucose, lactate dehydrogenase (LDH) and lactate were all analysed on an Hitachi 717

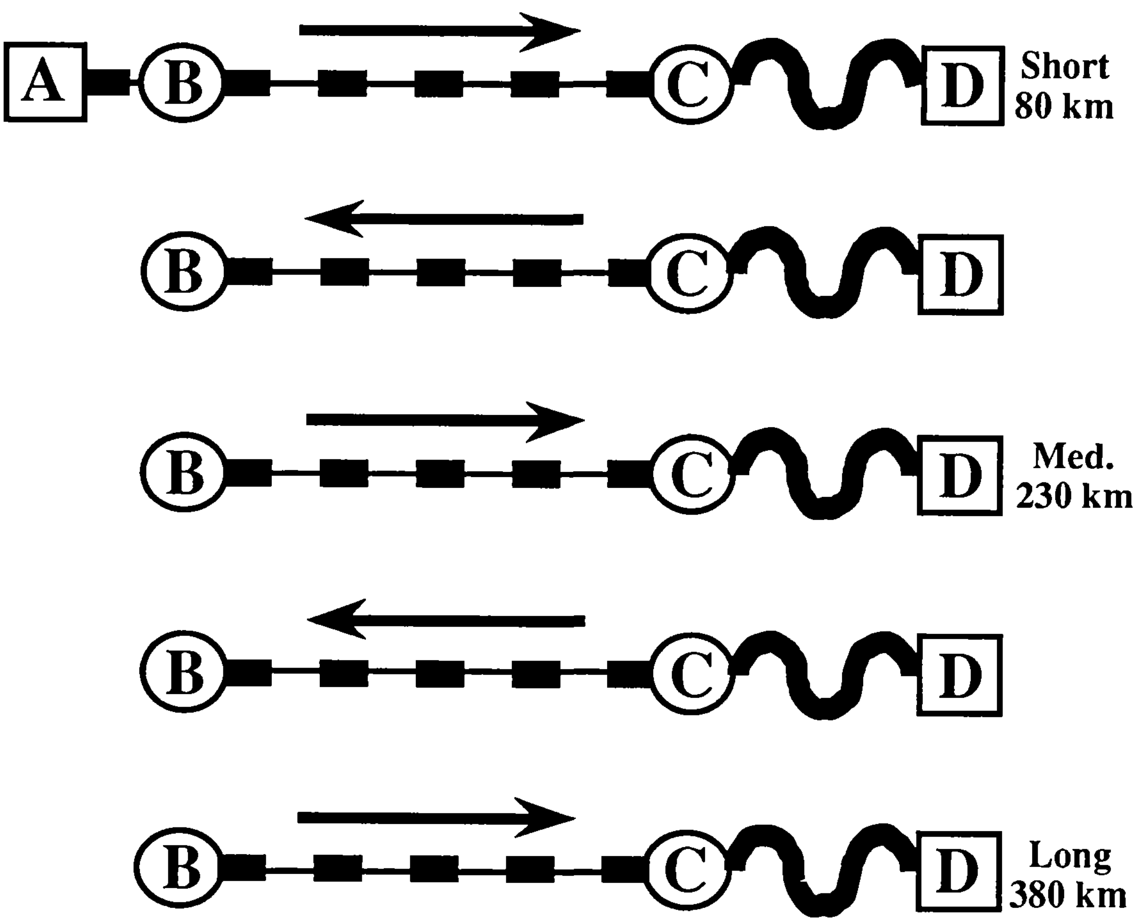

Figure 1. Transport route. The short journey length was 80 km and was a direct trip from the Ruakura Deer Unit yards (Point A), to The DSP (Point D). The medium journey length was 230 km. On these journeys the truck drove from Point A to Point D, then returned to Point B and then drove to the DSP (Point D). The long journeys were 380 km and included a second return trip to Point B and back to Point D. Darkened areas represent the periods that were observed as a subset of the entire journey.

Random Access Analyser using Boehringer Mannheim Kitset reagents. LDH isoenzymes were analysed using the Titan Gel Isoenzyme Procedure form Helena Laboratories. All enzymes were assayed at 30°C. Plasma sodium (Na) was analysed on a NOVA 4 ion specific electrode analyser. All analyses were carried out by staff at the Ruakura Animal Health Laboratories. Cortisol was measured by an indirect radioimmunoassay method.

Behaviour analysis

Two sets of behaviour observations were made by viewing the behaviour of animals that had been recorded on video cassette for the duration of each journey. The first involved viewing the entire journey and recording behaviours that were infrequent and of short duration. The second set of observations included behaviours that were occurring much of the time and these were measured by observing a sub-set of the entire journey.

The entire journey: For each animal the following was recorded: impacts (defined as a sudden movement through a distance 2-4 cm, as measured on the monitor, followed by contact with another animal or wall), agonistic behaviour (biting, climbing, boxing or kicking), and lying.
Sub-set of journey: Each tape was viewed a further 6 times during which the orientation, position and stance were recorded. The first five minutes (start) was observed to determine if the behaviour at the start of the journey differed from that exhibited during the remainder of the trip. From then on for each journey alternate 5 minute periods were observed coinciding with

the beginning of the flat section of the road (Point B) and ending at Point C. From Point C a 10 minute period was sampled which included the whole of the steep, winding section of the trip. For the longer journeys this procedure was repeated for the same sections of road on both the Hamilton and DSP bound journeys.

During each observation period the following behaviours were continuously sampled: *orientation:* the direction in which the individual was aligned (ie. the animal was assigned to one of eight equal sectors including front which was parallel to and facing the direction of travel, front - right, right, rear - right, rear, rear - left, left, and front - left); *position:* the pen was divided into 4 equivalent quadrants, the quadrant an individual was standing in at any one time was recorded; *stance:* it was recorded if the individual was standing stationary, walking, falling or lying; *rapid foot adjustments (RFA):* This was defined as small foot movements apparently to correct balance and avoid falling and could be identified by a sudden and rapid movement of the shoulders or hips.

Statistical analyses

Statistical analyses were carried out using the Genstat V statistical programme (Lowes Agricultural Trust, Rothamstead Experimental Station). The chemical data were analysed by an analysis of variance (ANOVA) testing the effect of journey length (treatment) on change in blood constituents against between truck variation. Behavioural data were calculated as behaviour(s) per hour and analysed by ANOVA testing for roadtype (start, flat divided into 5 sections, and hill), and lap (repeated sections of road on the longer journeys) effects against their respective interactions with truck. Differences in bruise score for various sites on the carcass were tested using the Kruskal-Wallis non parametric one-way analysis of variance.

RESULTS

The preslaughter handling period was divided into several different phases (ie. yarding, crushing, holding prior to transport, transport, lairage and slaughter). There were no significant differences in the time spent in each phase (except for the experimental variable). Although HCW did not differ significantly between groups or treatments, animals in the long journey groups had on average a smaller GR (3 mm) than those in the short and medium distance groups (6 mm and 5 mm, respectively).

On arrival at the DSP animals were alert and appeared in good physical condition. There was one exception on one of the long journeys in which one small animal was lying down on arrival and had to be encouraged to stand by the stock handler.

Behaviour during transport

Orientation. The percentages of times spent in each of the eight orientations was calculated for each animal for all observations at each section of the road (at the start, on the flat and on the hill) during the journey and averaged across groups for each distance travelled (treatment). There were no significant differences between treatments in the proportions of time spent in each orientation so data from all treatments (three journeys at each of three distances) were averaged. These data are shown in Table 2. The hinds tended to avoid the front-right/rear-left diagonal ($p < 0.05$) but spent approximately equal time in each of the other six orientations. As journey length increased there was no difference in the way animals oriented themselves.
Position. The percentage of time spent in each of four quadrants was calculated as for orientation. There were no differences in the proportions of time spent in the individual quadrants between treatments, road type or section of the journey.

Table 2. Mean (± s.e.m.) of percentage of time spent in each orientation and quadrant averaged over all groups and treatments.

Orientation	
Facing towards	Mean ± s.e.m.
front	11.7 ± 0.92
front-right	5.7 ± 0.60
right	12.7 ± 0.92
rear-right	16.4 ± 1.06
rear	15.4 ± 1.03
rear-left	7.7 ± 0.71
left	15.7 ± 1.06
front-left	14.6 ± 1.01

Agonistic behaviour. There was relatively little agonistic behaviour (between 2 and 17 instances per pen per hour) except on two of the long journeys in which 55 and 120 instances per pen per hour were observed. Bites were by far the most frequent agonistic behaviour accounting for 95.0% of all agonistic behaviour observed. Other behaviours included kicks (3.8%) and boxing (1.2%). Bites, kicks and boxing were grouped together and called agonistic behaviour. When ranked by HCW within a pen the heavier animals tended to initiate most of the agonistic behaviour which was typically directed at the smaller animals. The frequency of agonistic behaviour was relatively consistent for all stages of the journey (Table 3).
Impacts. Over all journeys there were more impacts during the first five minutes of the journey and while travelling on the hill than on the flat road ($p < 0.001$) (Table 3).
Rapid foot adjustments. The rate of rapid foot adjustments (RFA's) were calculated for each animal and there was no difference within or between treatments so data from all treatments and groups were averaged. On average there were more RFAs made during the start of the journey and while on the hill compared to the flat sections of the road ($p < 0.001$) (Table 3).

Table 3. Mean total number of agonistic behaviours, impacts and rapid foot adjustments made per hour by red deer hinds during different stages of the journey.

	Start	Flat	Hill
Agonistic Behaviour	5	4	6
Impacts	9	2	5
Rapid Foot Adjustments	66	25	51

Lying behaviour. On six of the nine journeys one or more animals lay down. Except for one animal, the deer did not lie down in the first 60 minutes of the journey. The percentage of animals that lay down during each hour of the journey (across all journeys) are shown in Figure 2. A larger percentage (33.3%) of animals lay down during the fourth hour of transport compared to the first three hours (1.9% to 8.3%). However, in the fifth hour the percentage decreased, but was still higher than for the first three hours of transport (16.7%). On two occasions an animal was observed attempting to lie down but appeared unable to do so because of insufficient space to complete the manoeuvre.

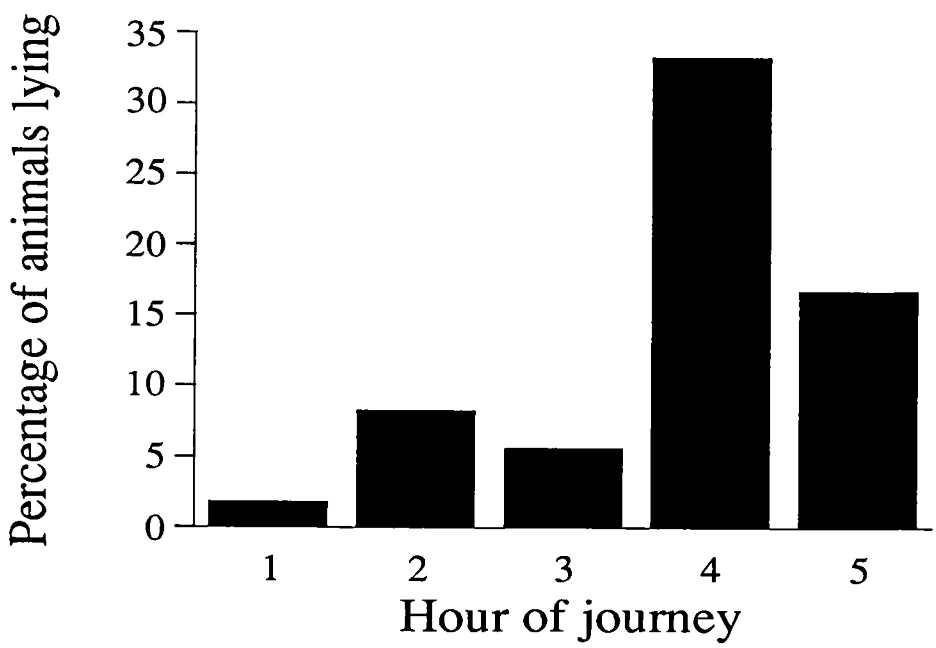

Figure 2. The proportion of animals that lay down in each hour of the journey, for all journeys and animals

Carcass and meat quality

There was a numerical increase in carcass bruise score with distance travelled however this was not significant ($p = 0.093$) (Table 4). The mean bruise score for animals transported the short and medium distances was 5.2 and 6.2, respectively. The bruise score for those animals that travelled the long distance was 10.7. Generally bruising occurred most frequently on the pin-bone region and hindquarter (rump, silverside, knuckle). Two deer recorded a bruise score much higher than any other animals. Both animals were on the same long distance trip and had scores of 26 and 44. The animal with the most severe bruising was small and lay down for long periods during the journey, and was often stood on by the other animals.

Muscle pH measured in the leg was consistently and significantly lower than that measured in the neck (mean difference = 0.417 ± 0.015, $p < 0.01$). Both leg and neck pH decreased with increasing distance transported (Table 4.12). Only two carcasses recorded a pH over 6.0 in the neck (6.02 and 6.03) and they both travelled the short distance but on different journeys.

Physiological response to handling and transport stress

The means of the changes in blood constituents measured before and after transport are shown in Tables 5. The differences in plasma concentrations of CK, total LDH, LDH 5 and LDH 4 between pre and post-transport samples increased with distance (signified by *'s next to the blood constituent name in Table 5). There was no substantial effect of distance transported on plasma AST, calcium, magnesium, chloride, glucose, sodium, lactate, cortisol, LDH 1, LDH 2 and LDH 3. Transportation (regardless of distance) caused a significant increase in the plasma concentrations of CK, AST, glucose, lactate, cortisol, total LDH, LDH 3, LDH 4 and LDH 5 and a decline in magnesium. Plasma calcium, sodium, LDH1 and LDH 2 were unaffected by preslaughter handling.

Table 4. The mean (± s.e.m.) carcass bruise score, mean bruise score for several carcass sites and carcass pH_{22} in red deer hinds following transport over three distances.

	Journey length			
	Short	Medium	Long	Significance[b]
Carcass bruise score	5.2 ± 0.8	6.2 ± 0.7	10.7 ± 2.3	n.s (p = 0.093)
Carcass site bruise score				
hock	0.6	1.2	1.6	** (H = 9.34)
pin-bone	1.8	2.5	3.1	n.s (H = 5.73)
hindquarter	1.4	0.8	2.7	* (H = 6.06)
ribs and brisket	0.4	0.9	1.9	n.s (H =1.74)
vertebrae and back	0.0	0.2	0.8	* (H = 8.20)
forequarter[a]	1.0	0.6	0.6	n.s (H = 0.99)
Muscle pH_{22}				
pH leg	5.42	5.37	5.37	*
neck pH	5.83	5.82	5.75	*

[a] forequarter includes the knee, elbow, shoulderblade, shoulder, joint and neck
[b] Level of significance: *** p < 0.001, ** p < 0.01, * p < 0.05, n.s not significant

Table 5. The arithmetic means of the changes in blood parameters for groups of deer transported three distances.

Blood Constituent[b]	Short (N = 18)	Mean Change Medium (N = 18)	Long (N = 18)	Overall[ab] mean (N = 54)
C.K (U/l) **c	162	345	1096	534 ***
A.S.T (U/l)	3.9	16.6	31.4	17.3 **
calcium (mmol/L)	-0.133	-0.061	-0.156	-0.117
magnesium (mmol/L)	-0.072	-0.035	-0.100	-0.069 **
glucose (mmol/L)	2.33	3.39	2.83	2.85 ***
sodium (mmol/L)	-0.72	-1.00	0.89	-0.28
lactate (mmol/L)	0.27	0.37	-0.33	0.11 **
cortisol (ng/ml)	18.6	15.6	10.5	14.9 **
LDH 5 *c	60	76	204	113.0 ***
LDH 4 *c	2.1	10.2	31.1	14.4 **
LDH 3	-3.9	49.9	63.1	36.4 **
LDH 2	-26.2	8.3	41.9	8.0
LDH 1	-101	25	-33	-36.0
Total LDH *c	-69	170	312	138 *

[a] The overall mean is the average change from zero for all 9 journeys
[b] Level of significance: *** p < 0.001, ** p < 0.01, * p < 0.05
[c] Significance levels indicate that differences in plasma concentrations between pre and post-transport samples increased with distance

DISCUSSION

This study has shown that preslaughter handling, including transport, results in changes in a number of behavioural and physiological parameters associated with stress, physical activity and injury. The distance travelled has an additional effect on some of these parameters.

Behaviour

Animals do not normally orientate randomly during transport. Studies on cattle have found that the most preferred orientations during transport are parallel to (Eldridge et al., 1986; Tarrant et al., 1988), or perpendicular to (Kenny and Tarrant, 1987a; Tarrant et al., 1992) the direction of travel. Similarly it has been shown that at low stocking densities ($0.74m^2$/animal) deer prefer to align themselves parallel to and facing the direction of travel and tend to avoid the diagonal orientations (Jago et al., 1993). In the current study the higher stocking density ($0.42m^2$/animal) appears to have prevented the animals from standing in their preferred orientation, as apart from the two diagonal orientations that were avoided, approximately equal amount of time was spent in the remaining six orientations. In addition, the larger animals had difficulty in facing parallel to the direction of travel as the pen from front to back was only 1.2 m. Instead they had to turn their head either to the left or right when their body was aligned parallel to the direction of travel.

The high rate of movements and rapid foot adjustments recorded during the first five minutes of the journey suggest that this is a settling down period after which the deer position themselves in relatively stable arrangements and become accustomed to the variable truck movements. As the rate of movements decreased after about eight minutes of transport it seems that deer settle relatively quickly at this density.

Winding roads caused an increase in the number of movements, rapid foot adjustments, and impacts with the truck or other animals. The rate of RFA's for both straight (approximately 25/hour) and winding (51/hour) roads were lower than reported for yearling stags (approximately 60/hour/animal and 120/hour/animal on the straight and winding roads respectively), at lower stocking densities than used here (Jago et al., 1993). Similarly, Tarrant et al., (1992) reported that losses of balance in cattle were most frequent at medium and low stocking densities whereas "falls" were most common at the high density. In the present study the deer were often in contact and often contacted each other as the truck made a turn or a gear change or braked. The support from other animals may have reduced the need to shift foot position to prevent losses of balance.

With the exception of one animal, deer did not lay down during the first 60 minutes of the journey. The incidence of lying is higher than that reported for cattle transported over the same distances. In one and four hour journeys no cattle lay down (Kenny and Tarrant, 1987a). On longer journeys (18 hours) cattle lay down more towards the end, particularly when travelling over smooth roads (Kent and Ewbank, 1983).

The stocking density used in this study is typical of that used by commercial transport operators. Observations during transport at this density ($0.42m^2$/animal) indicate that the normal behaviour of deer is being inhibited. On some occasions animals appeared to be prevented from lying and when they did manage to lie down, they usually stood up again within a few seconds as other animals stood on them. In addition animals were unable to stand normally in their preferred orientation, parallel to and facing the direction of travel.

Transport Stress

The elevations in plasma cortisol and glucose following transport are consistent with those described in response to acute stress such as preslaughter handling and transport in deer and other species (Hanssen et al., 1984; Tarrant et al., 1992; Kent and Ewbank, 1983). Although there was an overall elevation in these levels there was considerable individual variation in response to preslaughter handling as measured by plasma cortisol and glucose.

In exhausted animals glucose concentration can decrease, and the animals become hypoglycaemic (Shorthose and Shaw, 1977). One animal on a long journey lay down for long periods of time and had to be encouraged to stand up at the end of the journey. The plasma glucose concentrations for this hind decreased from 4.13 mmol/L before transport to 1.45 mmol/L after transport. This animal was also severely bruised.

Meat quality
The ultimate pH following transport was within the range previously reported for red deer hinds and within the range regarded as acceptable for sheep and beef (MacDougall et al., 1979; Kay et al., 1981; Smith and Dobson, 1990). The longer length of transport did not result in an increased muscle ultimate pH indicating that muscle glycogen stores were not significantly further depleted with the extra two or three hours travelling. The slight decrease in pH_{22} after longer transport was surprising as in other species it has been reported that the physical and psychological stress associated with longer duration transport causes an increased depletion of muscle glycogen, resulting in a longer period of recovery being necessary to prevent high pH_u meat (Shorthose et al., 1972; Wythes et al., 1988). The small deviation in pH between treatment groups although significant, was within the range of variation seen at slaughter and therefore the statistical differences are of dubious biological significance.

Carcass damage
With the exception of two animals, overall levels of bruising were low. Of the bruising recorded most was on the hocks and pin-bone where there is little or no muscle. The bruise score for hocks, and vertebrae/back increased significantly with distance transported. Pin-bone bruises also increased with distance transported however the increase was not significant. It is likely that hock and pin-bone region bruising are caused by impacts with the pen walls during transport and the longer the journey the higher the incidence of impacts and therefore bruising. Bruise score was negatively correlated with GR which agrees with the results of two previous studies on deer (Jago et al., 1993; Jago, 1994), and also a study on sheep (Knowles et al., 1994), which found that leaner animals had more bruising than fatter animals. The lower average GR of animals in the long distance groups may have contributed to the higher bruise score in these groups.

Within a group of deer the larger animals displayed the most agonistic behaviour and directed this at the smaller animals. On one long trip the majority of agonistic behaviour was initiated by one animal and directed equally at the other five animals. This hind had been introduced to the group four days prior to transport, and although there was little evidence of aggressive behaviour in the paddock, once confined in a small space the group became socially less stable. These observations have implications for transport operators as they provide evidence in support of the widely held belief that in order to reduce the amount of agonistic behaviour (and possibly bruising) during transport, deer to be penned together should be of similar size and familiar with each other. Studies with cattle have found that mixing unfamiliar groups of cattle results in increased physical activity (Mohan et al., 1992), agonistic behaviour and elevated levels of creatine kinase indicative of muscle damage (Kenny and Tarrant, 1987a).

Despite increases in bruise score for particular carcass sites with distance, it is clearly possible to transport hinds 380 km (5 hours) without detrimental effects on carcass and meat quality as measured by bruising levels and muscle pH_{22}. This was demonstrated on one of the long journeys. During this journey there was minimal activity in the pen and agonistic behaviour and the average carcass bruise score was low and similar to that for animals transported short distances.

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