Ultimate pH values and bacteriological condition of meat and stress metabolites in blood of transported reindeer bulls

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Abstract: Twenty-three reindeer bulls, aged 2-3 years, fed during two winter months at the Vuolda reindeer research station in Arjeplog, Sweden, were used in the study. The first group of eight reindeer was moved from their feeding corral to a selection corral, captured by lasso and stunned with a captive bolt outside the selection corral. The second group of seven reindeer was moved to the selection corral, captured by lasso and restrained, after which they were loaded onto a lorry and transported for 1h and then slaughtered. The third group of eight reindeer was moved to the selection corral and herded directly onto the lorry, without any manual handling. They were transported for 5 h and then slaughtered. In both transport groups, four reindeer were fitted with pre-programmed automatic blood sampling equipment (ABSE). ABSE sampled blood at predetermined times via a jugular vein catheter. Ultimate pH-values in three muscles (*Mm. longissimus, triceps brachii* and *biceps femoris*) were significantly lower in the group carefully handled and transported for 5 h compared with the other two groups. The physiological mechanisms behind these results are discussed. Samples from *M. semimembranosus* were collected at slaughter and after 2, 6 and 10 days of refrigerated storage (+4 °C). The samples were analysed for total counts of aerobic bacteria (pour-plated in Tryptone Glucose Extract Agar, Difco, incubated at 20 °C and 30 °C, respectively for 72 h), coliform bacteria 37 °C (pour-plated in Violet Red Bile Agar, Oxoid, incubated at 37 °C for 24 h), Enterococci (surface-plated onto Slantez and Bartley Agar, Oxoid, incubated at 44 °C for 48 h) and Bacillus cereus (surface-plated onto Blood Agar Plates (Blood Agar Base, Difco, supplemented with 5% defibrinated horse blood) 30 °C for 24 h). All samples fell in the range 'fit for consumption'. At slaughter, there was no difference in ASAT activity, urea and cortisol concentrations between the two transported groups. However, the plasma ASAT activity and urea concentrations at slaughter were significantly lower in the non-transported group. In both transport groups, the plasma cortisol concentrations increased during loading onto and unloading from the lorry. Abomasal lesions were observed in all treatment groups. It was concluded that reindeer showed an acute stress response to manual handling and transport.

Key words: animal welfare, ASAT, cortisol, meat, microbiological quality, *Rangifer tarandus tarandus*, transport, ultimate pH, urea.

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Introduction

The pre-slaughter handling of animals has an important effect on the quality of meat as well as implications for animal welfare (Warriss, 1993; Gregory, 1996, Goddard, 1998). In reindeer, meat quality traits (ultimate pH values and sensory

quality) as well as muscle glycogen content have been compared between animals handled differently pre-slaughter and animals shot undisturbed in the mountains. From these studies it was concluded that helicopter herding, lorry transport and lairage at the slaughterhouse did not significantly affect glycogen content or ultimate pH values in the muscles (Wiklund *et al.,* 1995; 1996a; 1996b; Malmfors & Wiklund, 1996). The traditional lasso selection technique however, was evidently a very stressful handling procedure and caused glycogen depletion (Essén-Gustavsson & Rehbinder, 1984, Wiklund *et al.*, 1996b; 1997a).

Whilst the impact of stress on the behaviour has been studied in some species of deer (Diverio *et al.*, 1993), measuring changes in blood parameters might result in a better appreciation of these effects. Conventionally, such studies require the animal to be restrained to allow collection of blood samples, but it is widely recognised that it is almost impossible to measure the normal levels of some blood constituents in captured and restrained reindeer as the stress associated with restraint and sampling will influence the values obtained (Rehbinder & Edqvist, 1981). Automatic blood sampling equipment (ABSE) has previously been used in reindeer (Wiklund *et al.,* 1994), red deer and sheep (Ferre *et al.*, 1998) and found to be a potentially valuable approach to monitoring stress. Evidence from reindeer showed that the process of blood sampling caused a five-fold increase in the plasma concentration of cortisol compared with ABSE (Saarela *et al.,* 1999).

The purpose of the present investigation was firstly to compare the combined effect of pre-slaughter handling/restraint and two transport alternatives (short and long road transport for one hour and five hours respectively) on ultimate pH values in meat and blood parameters, and secondly to measure changes in blood parameters during transport by use of ABSE. A third objective was to correlate blood parameters with ultimate pH values and microbiological condition of the meat.

Material and methods

Twenty-three reindeer bulls, aged 2-3 years, fed during two winter months at the Vuolda reindeer research station in Arjeplog, Sweden, were used in the study. They were fed a commercial feed mixture (Renfoder Extra, Fodercentralen, Holmsund, Sweden) and had free access to water in electrically heated watercups. The reindeer were kept in small grazing corrals in groups of 8, 7 and 8 animals. It was decided to keep the original groups in order to avoid ranking fights. When used in the experiments, the animals were walked through a system of pathways ending in a selection corral with a diameter of about 5 m.

The first group of eight reindeer was captured by lasso and stunned with a captive bolt outside the selection corral. Bleeding of the animals and inspection of the carcasses, skins and organs were performed outside the selection corral. The abomasal mucosa from all reindeer was examined for the presence of mucosal lesions and haemorrhages and rated on a scale from 0 (not affected) to 4 (severe lesions).

From the second group of seven reindeer, four animals were transferred to the selection corral and then put in a stable (1 reindeer/pen) where the ABSE was fitted to them and they were kept overnight. The remaining three reindeer in the group were left in their feeding corral. The following morning the reindeer from the feeding corral were moved to the selection corral, captured by lasso, restrained and loaded onto a lorry. The animals fitted with the ABSE were loaded on the same lorry, and all seven reindeer were transported for 1 hour. After transport they were released into the selection corral, taken by hand and stunned with a captive bolt. The *post mortem* procedure was the same as for the first group.

Finally, from the remaining group of eight reindeer, four reindeer were fitted with ABSE as described above and the remaining four animals were left in their feeding corral overnight. The following morning the animals from the feeding corral were walked through a system of pathways and herded directly onto the lorry without touching them. The animals fitted with the ABSE were loaded in the same way. All eight reindeer were transported for 5 hours. After the transport they were released into the selection corral, taken by hand and stunned with a captive bolt. The *post mortem* procedure was the same as for the two previous groups.

Automatic blood sampling

The pre-programmed automatic blood sampling equipment (ABSE) (Goddard *et al.,* 1998) was fitted to the animals on the day prior to the study and commenced collection of samples at 08.30 h

the following day, between 16 and 19 h later. Samples were collected every 15 min (1-h journey) or every 30 min (5-h journey). On recovery of the equipment, blood samples were centrifuged, the plasma frozen in liquid nitrogen (-196 °C) and stored at - 80 °C until analysis.

pH measurements

For calibration of the pH equipment, buffers of pH 7.0 and 4.0 (Merck) at room temperature were used. Ultimate pH was measured with a portable pH meter (Portamess 651-2, Knick Elektronische Messgeräte GmbH & Co, Germany) equipped with a Xerolyte electrode (lot 406 M-6, Ingold Messtechnik AG, Switzerland), in *M. longissimus* (at the last rib), *M. biceps femoris, M. triceps brachii* and *M. semimembranosus* at 24 h *post mortem*.

Blood parameters

Plasma samples were analysed for aspartate aminotransferase (ASAT), urea and cortisol. ASAT activity was determined by a kinetic technique on an LKB Reaction Rate Analyser according to the recommendations of the Scandinavian Committee on Enzymes (1974). Urea concentrations were determined by means of a glucose/urea/creatinine analyser (IL 919; Instrumentation Laboratories) using reagents and procedures recommended by the manufacturer. Cortisol was assayed with an enhanced luminescence immunoassay technique (AmerliteR, Kodak Clinical Diagnostics Ltd., England). Serial dilutions of reindeer plasma containing high concentrations of cortisol produced displacement curves parallel to the standard curve.

Bacteriological investigation

Samples from *M. semimembranosus* were collected at slaughter (day 0) and after 2, 6 and 10 days of refrigerated storage (+4 °C). The samples were transported refrigerated in a chilly bin to the lab for analysis. For bacterial count, 10 g of the muscle samples were removed and put into a sterile plastic bag together with 0.1% peptone water (Oxoid) to obtain a 1:10 dilution. The samples were then homogenised in a Stomacher for about 2 minutes. For quantitative analysis, ten-fold serial dilutions were made in 0.1% peptone water (Oxoid).

The samples were analysed for total counts of aerobic bacteria (pour-plated in Tryptone Glucose Extract Agar, Difco, incubated at 20 °C and 30 °C, respectively for 72 h), coliform bacteria 37 °C (pour-plated in Violet Red Bile Agar, Oxoid, incubated at 37 °C for 24 h), *Enterococci* (surface-plated onto Slantez and Bartley Agar, Oxoid, incubated at 44 °C for 48 h) and *Bacillus cereus* (surface-plated onto Blood Agar Plates (Blood Agar Base, Difco, supplemented with 5% defibrinated horse blood) 30 °C for 24 h). The Blood Agar Plates were also used to get an overview of the hemolysin producing bacteria.

Statistical analyses

The statistical analyses were carried out with the Statistical Analysis System (SAS Institute Inc., 1997, version 6.12) using the GLM and MIXED procedures. The model for comparing pH values included the fixed effects of treatment group and muscle, the random effect of animal nested within treatment group, and also the interaction (treatment group x muscle). The model for comparing blood parameters during transport included the fixed effects of treatment group and sampling time and the random effect of animal nested within treatment group. When comparing blood parameters at slaughter and abomasal lesions, the model included the fixed effect of treatment group. As in earlier studies (Wiklund *et al.*, 1995, 1996a, 1996b, 1997a) pH values were converted in the statistical analyses to hydrogen ion concentrations and when presenting the mean values they were transformed back from estimates on the concentration scale. Standard errors, however, became non-symmetric and error ranges on the pH scale were therefore calculated from the estimated means ± standard errors.

Results

Ultimate pH

Ultimate pH values in three muscles (*Mm. longissimus, triceps brachii* and *biceps femoris*) were significantly lower in the group carefully handled despite being transported for 5 h (Table 1). When comparing the two transport groups, the ultimate pH value in *M. semimembranosus* was significantly higher in the group transported for 1 h compared with the group transported for 5 h (Table 1). In all treatment groups, *M. semimembranosus* had the significantly lowest ultimate pH value compared with the other three muscles (Table 1).

Table 1. Ultimate pH values in *Mm. longissimus, biceps femoris, triceps brachii* and *semimembranosus* and ASAT, urea and cortisol concentrations in blood plasma at slaughter (least-squares means ± standard errors) for reindeer bulls from three treatment groups, and the degree of significance for the effects of treatment group and muscle. Abomasal lesions rated on a scale from 0 (not affected) to 4 (severe lesions)

Trait	No transport (captured by lasso and stunned, n=8)	Transport 1 h (captured by lasso and restrained, n=7)	Transport 5 h (restraint avoided, n=8)	Degree of sign., treatment group[1)]
pH value[2)]				
M. longissimus	5.68^{a1} (5.65 - 5.71)	5.73^{a1} (5.69 - 5.77)	5.58^{b1} (5.55 - 5.60)	***
M. biceps femoris	5.78^{a2} (5.75 - 5.83)	5.80^{a2} (5.76 - 5.85)	5.64^{b1} (5.61 - 5.68)	***
M. triceps brachii	5.87^{a2} (5.82 - 5.92)	5.91^{a2} (5.85 - 5.97)	5.74^{b2} (5.70 - 5.78)	**
M. semimembranosus	5.53^{ab3} (5.51 - 5.55)	5.59^{a3} (5.57 - 5.62)	5.49^{b3} (5.47 - 5.51)	***
Degree of sign., muscle [1)]	***	***	***	
ASAT, µkat/l	1.52^{a} ± 0.4	3.14^{b} + 0.4	2.99^{b} ± 0.4	**
Urea, mmol/l	8.1^{a} ± 0.8	11.3^{b} ± 0.9	11.1^{b} ± 0.8	**
Cortisol, nmol/l	77.8 ± 15.5	63.4 ± 16.5	81.1 ± 15.5	n.s.
Abomasal lesions	0.4 ± 0.4	0.8 ± 0.4	1.1 ± 0.4	n.s.

[1)] n.s.=P>0.05; **=P≤0.01; ***=P≤0.001.

[2)] Least-squares means and ranges for means ± standard errors were reconverted from the concentration scale.
Within-row means having the same superscript (letters) are not significantly different (P>0.05).
Within-trait means in the same column having the same superscript (numbers) are not significantly different (P>0.05).

Bacteriological investigation

The total number of aerobic bacteria (both 20 °C and 30 °C) ranged from 100 - 100 000 cfu (colony forming units)/g meat. The larger numbers were preferably seen in the samples from the day of slaughter (day 0) and after 10 days storage at +4 °C, and the lower numbers after 2 and 6 days of refrigerated storage (Figs. 1 and 2). In the group transported for 5 h, the total number of aerobic bacteria (20 °C) were 1 log larger compared with the two other groups in the samples from day 0 and after 2 and 10 days of refrigerated storage. All values fell in the range 'fit for consumption'.

The number of coliform bacteria (37 °C) was less than 100 cfu/ g meat in all samples except one. This sample came from a carcass that was contaminated with faeces and had a coliform count of 360 cfu/g meat at day 0 and 11 500 cfu after 2 days of refrigerated storage. The number of *Enterococci* and *Bacillus cereus* were less than 100 cfu/g meat in all samples.

Blood parameters and abomasal lesions

At the time of slaughter, ASAT and urea levels were significantly higher in the two transported groups compared with the non-transported group (Table 1). During the lorry transport, plasma concentrations of ASAT and urea remained at the same high level in the transported groups (1-h journey and 5-h journey) and both groups showed similar values (Figs. 3 and 4).

Both transported groups revealed a marked increase in plasma cortisol in association with loading and unloading (Figs. 3 and 4). In the group transported for 1 h, there was a trend (P=0.14) towards a decline in cortisol during the

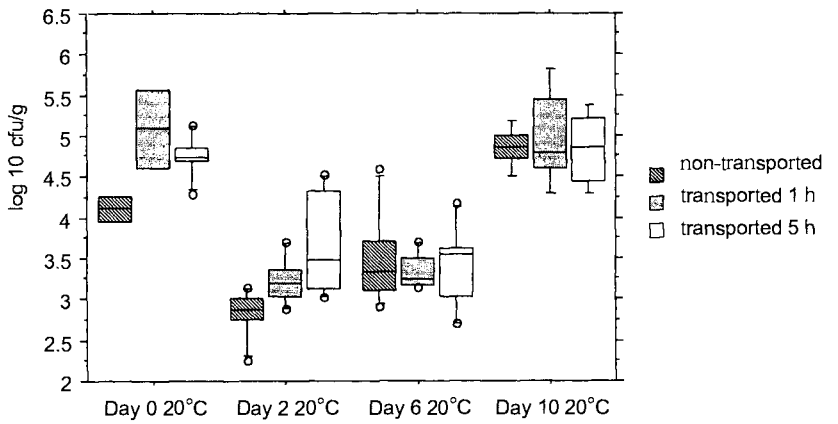

Fig. 1. The amount of aerobic bacteria at 20 °C in samples from reindeer bulls included in the study (non-transported, n=8; transported 1 h, n=7 and transported 5 h, n=8). The boxes in the figure show values between 25th and 75th percentile, the mean values are represented by the line in the boxes. So-called extreme values, which are below the 10th percentile and above the 90th percentile, are shown as circles in the figure.

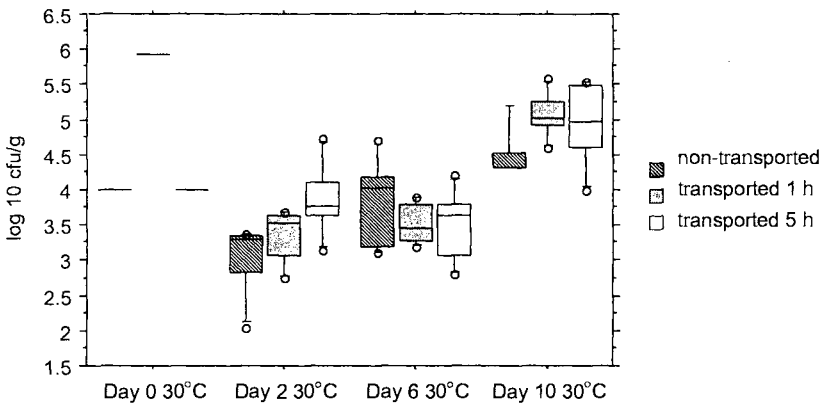

Fig. 2. The amount of aerobic bacteria at 30 °C in samples from reindeer bulls included in the study (non-transported, n=8; transported for 1 h, n=7 and transported for 5 h, n=8). The boxes in the figure show values between 25th and 75th percentile, the mean values are represented by the line in the boxes. So-called extreme values, which are below the 10th percentile and above the 90th percentile, are shown as circles in the figure. There are no boxes at day 0 because most of the values were below 4.0 cfu/g, which were the lowest dilution for the serial at day 0.

period of transport (Fig. 3). The group transported for 5 h showed a significant (P≤0.001) rise in cortisol when loaded onto the lorry and a significant (P≤0.001) decline in cortisol during the period of transport (Fig. 4). During the 5-h journey the driver had to take a short break. The reindeer reacted with a significant (P≤0.05) rise in plasma cortisol as soon as the lorry stopped and a significant (P≤0.05) decline in cortisol when the journey continued (Fig. 2). At slaughter, there were no significant differences in cortisol concentrations or in the frequency of abomasal lesions between the three treatment groups (Table 1).

Discussion

ASAT activities has been shown to increase when reindeer are herded, driven and manually handled (Nieminen, 1980; Rehbinder *et al.*, 1982) and provide an indication of muscle degeneration. An increase in urea concentration may be seen in connection with stress-induced muscular lesions, and has also been reported as an indication of catabolism of proteins due to mal- and under-nutritional intake of energy or to stress (Hyvärinen *et al.*, 1976; Rehbinder & Edqvist, 1981; Essén-Gustavsson & Rehbinder, 1984). Reindeer are known to have a low capacity to gain weight during winter compared to summer (White & Fancy, 1986), but it is still possible to gain between 0.1 and 0.2 kg live weight (0.05 - 0.10 kg carcass weight) per day in reindeer fed mainly commercial reindeer feed (Åhman, 1996; Nilsson *et al.*, 1996). The reindeer in the present study were fed commercial reindeer feed and hay *ad lib.* and gained weight despite being in their catabolic season. Therefore it may be concluded that the increased levels ASAT and urea might be indicative of muscular lesions caused by stress. Wiklund (1996) reported on increased ASAT and urea levels in connection with lorry transport (distance >500

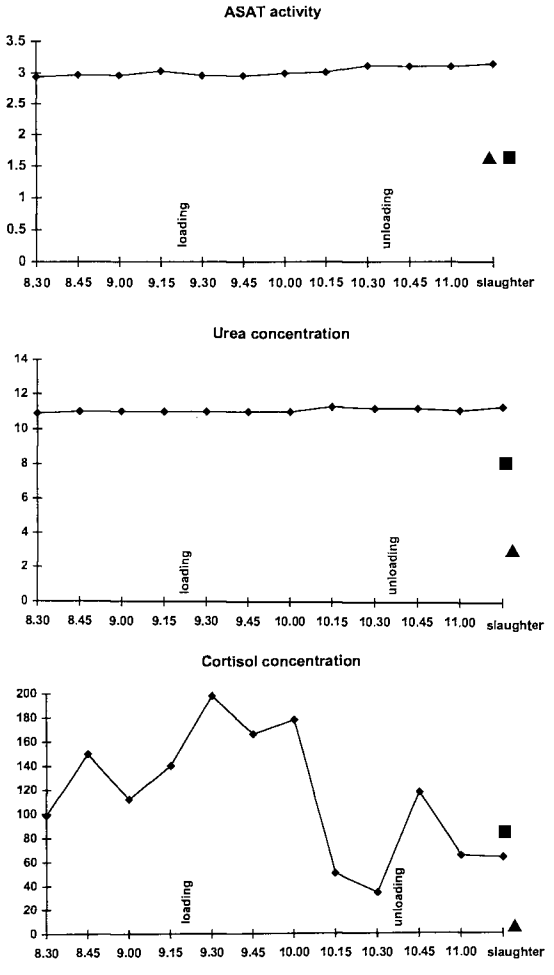

Fig. 3. ASAT (µkat/l), urea (mmol/l) and cortisol (nmol/l) concentrations in blood plasma for reindeer bulls (least-squares means) during road transport for 1 h (n=4). Slaughter values for the non-transported reindeer in the present study (■) and values for totally unstressed reindeer (▲, Rehbinder *et al.*, 1982) are included in the figure.

km). Selection of reindeer, using the traditional lasso technique, resulted in elevated ASAT as well as urea levels. The same author also demonstrated that reindeer in good nutritional status had lower levels of ASAT and urea. The results from the present study showed significantly higher ASAT activities and urea concentrations in reindeer subjected to intensive manual handling (captured by lasso, restrained, loaded onto and unloaded from the lorry) compared with the animals captured by lasso and then stunned. It should be noted that the measured ASAT activities and urea and cortisol concentrations in the present study (Figs. 1 and 2) were high when compared with levels found in totally unstressed reindeer (1-2 µkat/l, 1-5 mmol/l and 2-10 nmol/l, respectively) (Rehbinder & Edqvist, 1981; Rehbinder *et al.*, 1982; Wiklund *et al.*, 1996b; 1997a). In the present study it was confirmed that various kinds of restraint and handling initiate a general stress-response. The stress response might be correlated with the tameness of the

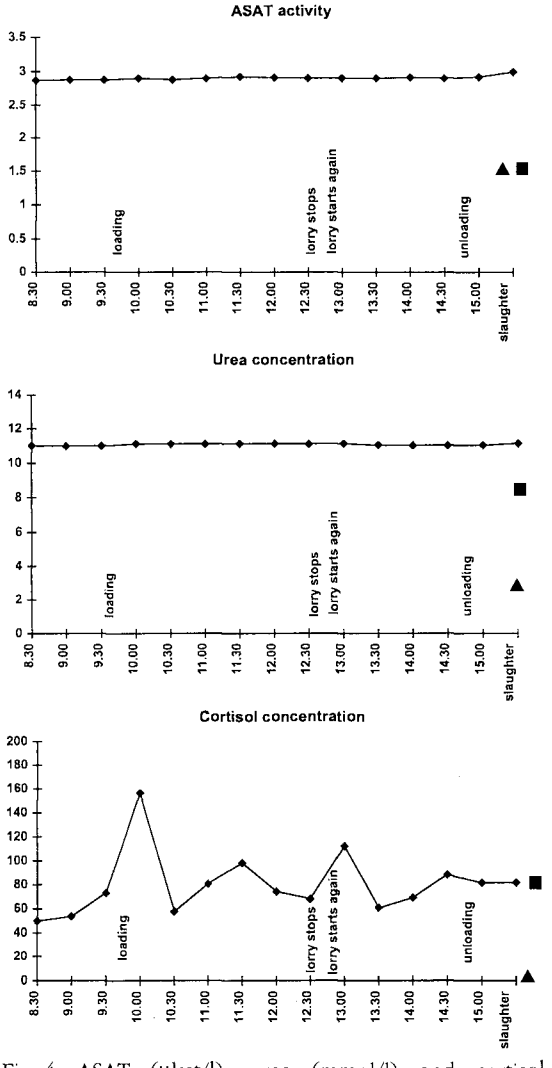

Fig. 4. ASAT (µkat/l), urea (mmol/l) and cortisol (nmol/l) concentrations in blood plasma for reindeer bulls (least-squares means) during road transport for 5 h (n=4). Slaughter values for the non-transported reindeer in the present study (■) and values for totally unstressed reindeer (▲, Rehbinder *et al.*, 1982) are included in the figure.

individual reindeer as well as the tameness of the herd. The impact of a stressor may also be correlated to the perception of something happening or appearing and the behavioural response of the herd and the individual animal to different kinds of disturbance (Rehbinder, 1990). It is well known that reindeer rapidly become accustomed to disturbances and activities (i.e. helicopters and snowmobiles) which, when introduced, cause great fear in the whole herd. The importance of correct handling, the individual response and the animals adaptation to a specific situation was demonstrated by Wiklund *et al.* (1994).

Cortisol has been used as a marker for acute stress in reindeer (Rehbinder *et al.*, 1982), veal calves (Trunkfield & Broom, 1990; Trunkfield *et al.*, 1991), cattle (Eichinger *et al.*, 1991), sheep (Fulkerson & Jamieson, 1982) and red deer (Diverio *et al.*, 1996). Previously, high cortisol concentrations indicated that almost all reindeer develop an acute unspecific stress response in connection with capture and restraint, i.e. as well during the traditional lasso selection procedure as when selected by hand (Wiklund *et al.*, 1994; Wiklund, 1996). The use of the ABSE technique in the present study made it possible to clearly show variations in cortisol concentrations in relation to the kind of stress the animals were exposed to. Hence, cortisol concentrations increased when the reindeer were loaded and unloaded and when the driver stopped the lorry for a short break, while the cortisol levels decreased during the transport. It is possible that the absence of direct human contact allowed the animals to calm down. As found by Harthorn (1981) any kind of protection, which wild ungulates could hide behind, would cut down the mortality rate. The varying cortisol concentrations during transport in the present study, might be due to the protection offered to some animals by the walls of the crate. In addition, no differences in cortisol concentrations between the three treatment groups were found at slaughter. The results of the present investigation confirm the results from previous reports that reindeer are markedly sensitive to all kinds of manual handling.

Manual handling and restraint have been found to cause severe muscle glycogen depletion in reindeer (Essén-Gustavsson & Rehbinder, 1984). A broad variation in muscle glycogen content and ultimate pH values in meat was related to different pre-slaughter treatments (Skjenneberg *et al.*, 1974; Wiklund, 1996). Of the investigated pre-slaughter handling procedures (helicopter herding, selection by lasso or by hand, lorry transport and lairage before slaughter), it was only the lasso selection procedure which resulted in increased ultimate pH values and thereby a risk of shortened shelf life of the meat (Wiklund *et al.*, 1995; 1996a; 1996b; 1997a). In the present study, the group of reindeer exposed to a minimum of handling and transported for 5 h had significantly lower pH values in *Mm. longissimus, triceps brachii* and *biceps* femoris compared with the two lasso selected groups. However, in the present investigation it was not possible to separate and study the particular and varying effects of pre-slaughter handling, transport and capture on the intra muscular glycogen content and finally the resulting ultimate pH in the meat.

Studies of the fibre morphology of reindeer muscles show that some of these, i.e. *M. longissimus,* contain a large proportion of IIB fibres, usually characterised by its fast contractile properties and glycolytic capacity (Kiessling & Rydberg, 1983; Essén-Gustavsson & Rehbinder, 1984). In reindeer, the IIB fibres are both highly glycolytic and remarkably oxidative, providing the reindeer with both speed and endurance to escape predators (Kiessling & Kiessling, 1984; Essén-Gustavsson & Rehbinder, 1985). The large proportion of IIB fibres in reindeer muscle has been suggested to account for the, for a ruminant, unusually rapid glycolysis (*post mortem* pH decline) in the meat (Wiklund *et al.*, 1997b). The basic metabolism in reindeer differs from that of domestic ruminants. The latter store their major energy reserves in the form of fat while in reindeer the protein stored in the IIB fibres constitute the major energy reserves (Kiessling & Rydberg, 1983; Kiessling & Kiessling, 1984). With a cyclic pattern of weight reduction in winter and compensatory growth in summer (Reimers, 1997), the protein turnover in reindeer muscle might be regulated by different pathways compared with domestic ruminants. Reindeer meat has been shown to be much more tender compared with beef which was explained with higher proteolytic enzyme activity and lower inhibitor levels in the meat (Barnier *et al.*, 1999). In man and horse it has been shown that musculature, after a forceful exercise, has a much shorter recovery period

if the forceful exercise is followed by a suboptimal exercise (Balsome *et al.*, 1992; Bangsbo *et al.*, 1994; Sullivan *et al.*, 1994). During normal transport the reindeer never lay down but they remain standing in a broad-bent position, holding their heads low using them as balance poles parrying the movements of the lorry (Skoglund, 1997) (Fig. 5). This position is kept throughout transport and this activity might be comparable with suboptimal exercise. It is possible that low frequency, mild and endurance exertion will facilitate a dilation of capillaries. Initially simply due to mechanical pumping activity and gradually as more and more metabolites are removed, intracellular metabolism starts. In reindeer, however, there are few reports on the glycogen metabolism in muscle fibres and more work is indicated.

In studies of the microbiological quality of reindeer meat, Hatakka *et al.* (1990) found that there was a large variation in pre-slaughter handling routines and hygienic standard among Finnish reindeer abattoirs. One slaughter plant produced 90% DFD (pH>6.00) carcasses and 34% of the meat samples from these carcasses fell into the poorest quality class on the basis of their aerobic plate count. The high frequency of DFD carcasses in Finland was found to be a problem for the processing of mainly cold smoked products, as the quality of these smoked products deteriorates markedly if the meat has a high pH value (Niinivaara & Petäjä, 1984). Reindeer meat of high pH (pH>6.10) was reported to have reduced shelf life (Wiklund & Smulders, 1997). In the present study *M. semimembranosus* was used for the microbiological investigation as it is one of the most valuable cuts. The ultimate pH values in *M. semimembranosus* were low (5.43 - 5.65), all investigated meat samples were considered to be of good hygienic quality and were classified as fit for consumption even after 10 days of refrigerated storage. None of the meat samples reached the 10^6 CFU (Colony Forming Units)/g) level, which is considered to be a critical limit for hygienic and sensory quality of meat. However, the present investigation also included higher ultimate pH values (5.47 - 6.30) in *Mm. longissimus, biceps femoris* and *triceps brachii* (where no microbiological studies were carried out) and, as reported earlier (Tarrant, 1989), there is a risk of reduced shelf life of meat at ultimate pH values ≥5.80.

Fig. 5. The position a reindeer takes when transported on a lorry. Reindeer remain in this standing position during the time it is transported using neck and head as a balance pole when parrying the bumps and other movements produced by the road and the lorry itself (drawing by S. Nikander, 1999).

It is concluded that there remain several important questions to be answered concerning stress and reindeer welfare. To be frightened and to have the perception of something being dangerous is a very important protective factor, necessary for the survival of the animal: stress is thus not always a negative factor. The 'normal' stress reactions in various daily activities and in different alert situations have not been measured in reindeer. There is also lacking a generally accepted method how to measure the stress load affecting an animal. In some animals the amount of IgA in the saliva has been shown to be a reliable integrated method that also has the advantage of being non-invasive (Skandakumar *et al.*, 1995). Using combined methods it will be possible to recommend pre-slaughter handling techniques for reindeer safeguarding both animal welfare and meat quality.

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