# Pre-slaughter handling of reindeer bulls (*Rangifer tarandus tarandus* L.) – effects on technological and sensory meat quality, blood metabolites and muscular and abomasal lesions

**E. Wiklund[1]*, G. Malmfors[1], K. Lundström[1] & C. Rehbinder[2]**

[1] Swedish University of Agricultural Sciences, Department of Food Science, P. O. Box 7051, S-75007 Uppsala, Sweden. e-mail: eva.wiklund@lmv.slu.se

[2] National Veterinary Institute, P. O. Box 7073, S-750 07 Uppsala, Sweden.

*Corresponding author.

*Abstract:* Forty-one reindeer bulls (age 1½ years) were subjected to different pre-slaughter treatments: herding for a short distance to a grazing corral, selection by use of a lasso, lorry transport and helicopter herding for 1, 2 and 3 days respectively. As control, 9 reindeer were shot without previous handling (in the mountains). The results indicated the traditional selection technique of using a lasso to be the most stressful and glycogen-depleting handling procedure so far studied. In the lasso-selected reindeer the lowest glycogen values and the highest ultimate pH values in the meat were measured. The values of the measured parameters indicating stress (aspartate aminotransferase (ASAT), urea, cortisol and abomasal lesions) were also highest in these reindeer. By contrast, the modern method of herding by helicopter was not found to be detrimental to glycogen content, ultimate pH, the measured blood metabolites, or the frequency of abomasal lesions. In all treatment groups degenerative lesions were observed in the skeletal muscles. No relarionship between technological and sensory meat quality characteristics and skeletal muscle lesions in reindeer could, however, be found in this study. The study confirmed an earlier finding that a 'stress-flavour' could develop in reindeer meat after intensive pre-slaughter handling of rhe animals. Further study of when and how such 'stress-flavour' develops ought to be undertaken.

Key words: *Rangifer tarandus tarandus* L, meat quality, sensory quality, ultimate pH, muscle glycogen, urea, ASAT, cortisol, abomasal lesions, muscular lesions.

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## Introduction

Modern reindeer management often includes stress factors such as rounding up, herding, road transport and long pre-slaughter lairage times. Such stress factors are arguably detrimental to animal welfare (Rehbinder *et al.*, 1982; Rehbinder, 1990). Nevertheless, road transport by lorry and 2 days' pre-slaughter lairage did not significantly impair meat quality traits (i.e. ultimate pH values and glycogen content) in *Mm. longissimus dorsi, biceps femoris* and *triceps brachii* (Wiklund *et al.*, 1996). Meat from reindeer carcasses has sometimes been reported to have extremely high ultimate pH values and low glycogen content (Petäjä, 1983; Wiklund *et al.*, 1995, 1996).

Most of the above-mentioned modern handling procedures expose the entire reindeer herds - or parts thereof - to a stressful situation, except for the

selection procedure by which animals are removed individually from the herd.

The purpose of this investigation was to study and quantify glycogen content and ultimate pH values in reindeer muscles and sensory quality of reindeer meat from animals (1) unaffected by manual or mechanical handling, (2) herded down from the mountains to a grazing corral by combined use of helicopter, snowmobiles and dogs, (3) captured in a traditional selection corral by use of the lasso, and (4) herded by helicopter for 1, 2 and 3 days respectively. Another objective was to study stress-induced blood metabolites and pathological changes in the abomasal mucosa and in three skeletal muscles (*M. longissimus dorsi, M. biceps femoris* and *M.triceps brachii*) following different handling procedures.

## Material and methods

The study was performed in Mellanbyn, a Saami community close to Gällivare in the northern part of Sweden. A total of 41 reindeer bulls (age 1 ½ years) were subjected to 7 different pre-slaughter treatments (Table 1).

Reindeer in groups A, E, F and G were shot in the head using a rifle (calibre 308 Winchester), while reindeer in the other groups were stunned with a captive bolt. From reindeer in groups A, E, F and G (shot in the mountains), blood and muscle samples were taken directly in the field, and the carcasses were then transported by helicopter to the slaughterhouse in Harrå. Reindeer in groups B, C and D were stunned in the selection corral or just outside the slaughterhouse in Harrå. Group D was allowed to rest for 2 days after the selection procedure before being transported by lorry 100 km to the slaughterhouse. While resting, they were offered hay and silage. One animal from group B was considered to be an outlier and was therefore excluded due to total glycogen depletion in all 3 muscles studied (4-32 mmol/kg dry weight) and high pH values (6.81-6.83).

Upon exsanguination, blood samples were collected in heparinized tubes, chilled, centrifuged and within 45 min after sampling, the plasma was frozen in liquid nitrogen (-196°C). Samples from *M. longissimus dorsi* (LD) (at the last rib), *M. biceps femoris* (BF) and *M. triceps brachii* (TB) were taken at approximately 15 min *post mortem* and frozen in liquid nitrogen. A piece of each muscle (1 $cm^3$) was fixed in 10% buffered formalin, embedded in paraffin, cut in 5µm thick sections and stained with haematoxylin-eosin and PTAH (Phosphotungstic Acid Haematoxylin). The samples were investigated for the presence of muscular lesions.

The abomasal mucosa from all reindeer was investigated for the presence of mucosal lesions and haemorrhages and rated on a scale from 0 (not affected) to 4 (severe lesions).

*Glycogen determination in muscle samples*

Muscle samples were freeze-dried for 24 h whereafter connective tissue, fat and blood were removed under a dissection microscope. Glycogen was analysed by assessing glucose residues after 1-2 mg of tissue had been boiled for 2 h in 1 M HCl (Lowry & Passoneau, 1973).

*Blood metabolites*

Plasma samples were analysed for aspartate aminotransferase (ASAT), urea and cortisol. ASAT was determined by a kinetic technique in an LKB Reaction Rate Analyser according to the recommendations of the Scandinavian Committee on Enzymes (1974). Urea values 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 luminescense 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. The intra-assay coefficients of variation calculated from 3 control samples were 12.1% (40 nmol/l), 8.1% (86 nmol/l) and 4.5% (543 nmol/l). The corresponding inter-assay coefficients of variation were 8.3%, 5.2% and 5.6%. The lowest amount of cortisol detectable (defined as intercept of maximal binding-2 SD) was 3.2 nmol/l.

*pH measurements*

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 Sweden, reindeer carcasses are not electrically stimulated and ultimate pH was measured in LD, BF and TB at 30 h *post mortem*.

*Sensory evaluation*

The saddle (the part of the back which is cut out between *vertebrae thoracales* 6-7 and *vertebrae lumbales*

Table 1. Characteristics of various treatment groups of reindeer included in the study.

| Treatment group | Number of bulls | Pre-slaughter handling procedure | Slaughter procedure |
|---|---|---|---|
| A | 9 | None. | Shot in the head with a rifle without previous handling. |
| B | 5[1)] | Herded and driven a short distance to a grazing corral by combined use of helicoprer, snowmobiles and dogs. | Captured by lasso immediately after entering the grazing corral (all 5 reindeer within 20 min). Manually restrained and stunned with a captive bolt in the grazing corral. |
| C | 6 | Same treatment as group B, then transferred to a selection corral and captured by lasso after 4 hours running in the selection corral. | Manually restrained and stunned with a captive bolt in the selection corral. |
| D | 5 | Same treatment as group C, then the group were put in a resting corral for 2 days with access to hay, silage and snow. The group was then transported by lorry over a distance of 100 km. | Manually restrained and stunned with a captive bolt just outside the slaughter house. |
| E | 5 | Same treatment as group B, then removed from the grazing corral before selection. Herded by helicopter for 1 day (20 km per day and allowing sufficient time for the reindeer to graze). | Shot in the head with a rifle. |
| F | 5 | Same treatment as group E, but herded by helicopter for 2 days. | Shot in the head with a rifle. |
| G | 5 | Same treatment as group E, but herded by helicopter for 3 days. | Shot in the head with a rifle. |

[1)] After exclusion of one animal, see Material and methods.

5-6) from each of 16 reindeer in groups A, B, C and G (4 from each group) was excised and packed in a plastic bag, kept refrigerated (at +3°C - +5°C) for 14 days and then frozen. The samples were then transported to Matforsk (Norwegian Food Research Institute, Ås, Norway) where the sensory analysis was performed. The reindeer saddles were split in two halves (right and left M. *longissimus dorsi*) and sawn into chops. The panel members always received their chops from the same part of the *longissimus* muscle. The chops were vacuum-packed and then heated in a waterbath to +65°C for 120 min. The sensory profile of the reindeer meat was assessed by a trained expert panel comprising 11 members, who applied a descriptive test (Stone & Sidel, 1985; Piggott, 1988). The questionnaire was formulated with special reference to reindeer meat. The definitions of the profile attributes are described in Table 2, and the panel scored the sensory attributes on a continuous intensity scale ranging from 0 (low intensity) to 9 (high intensity).

Table 2. Definitions of the sensory attributes used in the sensory profiling of the reindeer meat.

| Attribute | Definition |
|---|---|
| Intensity of odour | Intensity of any odour in the product. |
| Liver odour | Odour of liver, metallic. |
| Pungent odour | Strong and intense odour sensation. |
| Sickeningly sweet odour | Flat, stale odour. |
| Whiteness | Colour measured on a newly cut slice of meat, black or pure colour to white colour. |
| Hue | Yellow/red to red/blue. |
| Intensity of colour | Colour: none - intense. |
| Intensity of flavour | Intensity of any flavour in the product. |
| Liver flavour | Flavour of liver, metallic. |
| Sharp flavour | Strong and intense flavour sensation. |
| Sickeningly sweet flavour | Flat, stale flavour. |
| Acidic flavour | Primary taste produced by acid (e.g. citric acid, lemon). |
| Juiciness | Perception of juice absorbed from the product. |
| Hardness | Mechanical texture attribute measured by compressing the product between the teeth, force required to produce deformation of the product. |
| Tenderness | Mechanical texture attribute related to cohesiveness and to the length of time or the number of chews required to masticate a solid product into a state ready for swallowing. |

*Statistical analyses*

The statistical analysis was carried out with the Statistical Analysis System (SAS Institute Inc., 1995) using the GLM and MIXED procedures. The model for comparing pH values and glycogen content 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). As the interaction was non-significant for glycogen content, the overall effect of treatment group across muscles is shown (Fig. 1). For pH values, however, the interaction (treatment group x muscle) was significant and, for the sake of clarity, subgroup means for glycogen content are also presented, together with the corresponding pH values. The model for comparing blood metabolites and abomasal lesions included the fixed effect of treatment group. When the sensory attributes of the *longissimus* muscle from reindeer in groups A, B, C and G were compared, the model included the random effect of animal nested within treatment group

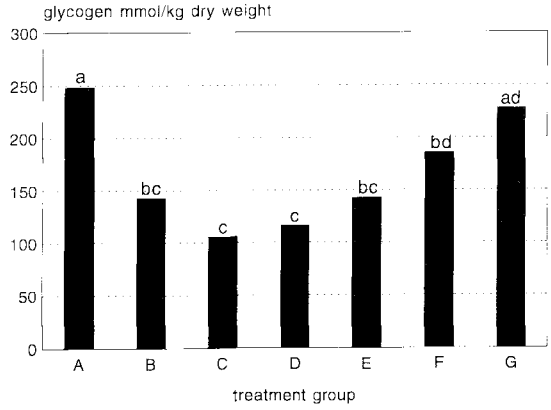


Fig. 1. Glycogen content (least-squares means) after different pre-slaughter handling of reindeer bulls when all studied muscles are taken into consideration (*Mm. longissimus, biceps femoris* and *triceps brachii*. For treatment groups and numbers investigated, see Table 1). Means with the same letters are not significantly different ($P>0.05$).

as well as the fixed effects of treatment group, panel member and the interaction (panel member x treatment group). The interaction (panel member x treatment group) was excluded from the model when not significant.

As in earlier studies (Wiklund *et al.*, 1995, 1996) pH values were converted in the statistical analyses to hydrogen ion concentrations and when presenting mean values they were reconverted from estimates on the concentration scale. Standard errors, however, become non-symmetric and error ranges on the pH scale were therefore calculated.

## Results

*Glycogen content and ultimate pH values*

The different pre-slaughter handling treatments affected the glycogen concentrations in the three muscles similarly (Table 3). Mean glycogen concentrations for the three muscles are shown in Fig. 1.

Groups A (shot without previous handling) and G (herded by helicopter for 3 days) had the highest content of glycogen in *Mm. longissimus dorsi, biceps femoris* and *triceps brachii* (see Table 3). After the herding down to a grazing corral close to the slaughterhouse, a significant part of the glycogen stores had been consumed (group B), while in reindeer subjected to the lasso selection procedure (group C) and to both lasso selection and subsequent lorry transport (group D) most glycogen had been consumed. During the helicopter herding (groups E, F, and G) the glycogen content increased significantly with longer herding times in all three muscles.

Group A showed the lowest ultimate pH values in *M. longissimus dorsi*, while in *M. biceps femoris* and *M. triceps brachii* the lowest pH values were found in groups A and G (see Table 3). As a result of the decrease in glycogen content after herding the animals down to the grazing corral (group B), the ultimate pH values increased in this group. The highest ultimate pH values, however, were measured in groups C, D (in all 3 muscles) and F (in *M. triceps brachii*). The ultimate pH values after 1 and 2 days of herding by helicopter were the same, but after 3 days of herding the pH values decreased.

*Blood metabolites, abomasal lesions and skeletal muscle lesions*

Group C showed the highest ASAT values, otherwise there were no significant differences between the groups (Table 4). However, group D also tended to

Table 3. Glycogen content and ultimate pH value in *M. longissimus*, *M. biceps femoris* and *M. triceps brachii* (least-squares means ± standard errors[1]) for reindeer bulls included in the study (for numbers investigated, see Table 1).

| | *Treatment group* | | | | | | |
|---|---|---|---|---|---|---|---|
| Trait | A No handling | B Before selection | C After selection | D Selection and transport | E Herded by helicopter 1d | F Herded by helicopter 2d | G Herded by helicopter 3d |
| Glycogen, mmol/kg dry weight | | | | | | | |
| *M. longissimus* | $287^{a1}$ ±8.8 | $168^{b1}$ ±11.8 | $124^{c1}$ ±10.8 | $130^{c1}$ ±11.8 | $167^{b1}$ ±11.8 | $208^{d1}$ ±11.8 | $244^{c1}$ ±11.8 |
| *M. biceps femoris* | $260^{a2}$ ±8.8 | $148^{b1}$ ±11.8 | $110^{c12}$ ±10.8 | $119^{bc1}$ ±11.8 | $148^{b1}$ ±11.8 | $210^{d1}$ ±11.8 | $236^{ad1}$ ±11.8 |
| *M. triceps brachii* | $198^{a3}$ ±8.8 | $111^{bc2}$ ±11.8 | $83^{b2}$ ±10.8 | $99^{b1}$ ±11.8 | $113^{bc2}$ ±11.8 | $138^{c2}$ ±11.8 | $202^{a2}$ ±11.8 |
| pH-value[1] | | | | | | | |
| *M. longissimus* | $5.50^{a1}$ 5.49-5.52 | $5.67^{bc1}$ 5.64-5.70 | $6.04^{c1}$ 5.98-6.12 | $5.83^{d1}$ 5.79-5.88 | $5.71^{b1}$ 5.68-5.74 | $5.71^{b1}$ 5.68-5.74 | $5.62^{c1}$ 5.59-5.65 |
| *M. biceps femoris* | $5.52^{a1}$ 5.51-5.54 | $5.68^{bd1}$ 5.65-5.71 | $6.06^{c1}$ 6.00-6.14 | $5.92^{c1}$ 5.87-5.98 | $5.77^{d12}$ 5.73-5.81 | $5.67^{bd1}$ 5.64-5.71 | $5.51^{a2}$ 5.49-5.53 |
| *M. triceps brachii* | $5.77^{a2}$ 5.74-5.80 | $5.96^{b2}$ 5.90-6.02 | $6.36^{c2}$ 6.24-6.52 | $6.21^{c2}$ 6.12-6.34 | $5.87^{b2}$ 5.84-5.94 | $5.96^{b2}$ 5.91-6.03 | $5.75^{a3}$ 5.71-5.79 |

[1] Least-squares means and ranges for means ± standard errors were reconverted from the concentration scale.
Means in the same row 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 ($P>0.05$).

Table 4. Blood metabolites and abomasal lesions (least-squares means ± standard errors) in reindeer bulls included in the srudy (for numbers investigated, see Table 1) and the degree of significance for the effect of treatment group.

| | *Treatment group* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Trait | A No handling | B Before selection | C After selection | D Selection and transport | E Herded by helicopter 1d | F Herded by helicopter 2d | G Herded by helicopter 3d | Degree of sign.[1)] |
| ASAT, µkat/l | $1.8^{a}\pm0.6$ | $1.3^{a}\pm0.8$ | $4.9^{b}\pm0.7$ | $2.5^{a}\pm0.8$ | $1.7^{a}\pm0.8$ | $1.9^{a}\pm0.8$ | $1.5^{a}\pm0.8$ | * |
| Urea, mmol/l | $8.0^{a}\pm0.4$ | $10.2^{c}\pm0.6$ | $18.7^{b}\pm0.5$ | $11.3^{c}\pm0.6$ | $8.7^{ac}\pm0.6$ | $2.0^{d}\pm0.6$ | 2.2 ±d0.6 | *** |
| Cortisol, nmol/l | $52.4^{a}\pm6.7$ | $52.6^{a}\pm9.2$ | $93.5^{b}\pm8.4$ | $170.4^{c}\pm9.2$ | $14.2^{d}\pm9.2$ | $16.4^{d}\pm9.2$ | $6.2^{d}\pm9.2$ | *** |
| Abomasal lesions | $0.1^{a}\pm0.1$ | $0^{a}\pm0.2$ | $1.2^{b}\pm0.2$ | $1.4^{b}\pm0.2$ | $0.6^{c}\pm0.2$ | $0^{a}\pm0.2$ | $0^{a}\pm0.2$ | ** |

[1)] *=$P\leq0.05$; **=$P\leq0.01$; ***=$P\leq0.001$.
Within-trait means having the same superscript are not significantly different ($P>0.05$).

produce high values. The urea values showed significant differences between groups, as groups A, E, F and G had low values and group C had the highest. The cortisol values were low in groups E, F and G, whereas in group A they were suprisingly high, showing the greatest individual within-group variation (mean 52.4, SD 62.8) compared with all other groups. Groups C and D had significantly higher cortisol values compared with the other groups. When investigating the abomasal mucosa it was found that groups C and D had the highest frequencies of lesions. Degenerative changes indistinguable from those of capture myopathy were present in all three skeletal muscles and all treatment groups. No relationship between technological and sensory meat quality characteristics and skeletal muscle lesions could be found in this study.

*Sensory evaluation*

For sensory evaluation of the meat, groups A, B, C and G were included. Significant inter-group differences were found regarding odour, colour and flavour attributes (Table 5). Group A had a stronger odour and flavour of liver, while the sharp and sickeningly sweet odour and flavour were much less pronounced in this group than in the other groups. Meat from reindeer in group A also had a lighter colour and tasted more acidic.

## Discussion

The different pre-slaughter handling procedures affected the muscle glycogen stores in different ways. Whereas herding reindeer down to the grazing corral (group B) and the selection procedure (groups C and D) depleted the glycogen stores significantly, the glycogen content of all muscles studied from helicopter herded animals were much higher (groups E, F and G) (Fig. 1). These results indicate that during the helicopter herding the reindeer were actually able to build up their glycogen stores rather than them being depleted, thanks to generous access to pasture and sufficient time to graze, while the combined effect of the stress of lasso selection and lorry transport (group D) decreased the glycogen stores significantly in *M. longissimus dorsi* even though the animals had access to feed for 2 days. McVeigh & Tarrant (1982) showed in cattle that when young bulls were stressed and their glycogen stores became depleted, it took 7 days of rest and normal feeding to restore the glycogen stores to resting values. Our earlier studies showed that glycogen stores were not reduced when reindeer were transported by lorry for distances up to 1000 km (Wiklund *et al.*, 1996), whereas manual handling and restraint caused severe depletion of glycogen (Essén-Gustavsson & Rehbinder, 1984). The results of the present study indicate that a herd-forming animal such as the reindeer is markedly sensitive to

the restraint stress associated with handling by the procedures used to remove individual animals from the herd/group.

DFD (dark, firm, dry) meat is a well-known quality defect that shortens shelf life, especially for vacuum-packed meat and also affects meat colour, texture and water-holding properties (Tarrant & Hood, 1981). Had the official Swedish DFD limit for beef been applied, with an ultimate pH value ≥ 6.2 in *M. longissimus dorsi*, 4 carcasses of the total of 41 (1 from group B and 3 from group C) would have been classified as DFD. The slaughter industry sometimes use a DFD limit of 5.8 in the *M. longissimus dorsi* for beef carcasses; in the present study the use of this limit would have classified 13 reindeer carcasses as DFD (2 from group B, 5 from group C, 4 from group D, 1 from group E and 1 from group F).

From earlier studies (Skjenneberg *et al.*, 1974; Petäjä, 1983; Wiklund *et al.*, 1995) it is known that various shoulder muscles in reindeer have lower glycogen content and higher ultimate pH values, compared with the *longissimus* muscle. This was also the case in the present study.

High plasma urea and ASAT values have been reported to indicate catabolism of proteins due to submaintenance energy intake, or to stress (Hyvärinen *et al.*, 1976; Nieminen, 1980; Rehbinder & Edqvist, 1981). Wiklund *et al.* (1996) obtained low ASAT and urea values from reindeer in good physical condition. Cortisol values have been used as a marker for acute stress in reindeer (Rehbinder *et al.*, 1982; Wiklund *et al.*, 1994). The cortisol values from the present study demonstrated the difficulties with shooting reindeer totally 'undisturbed' in the mountains, as individual animals were seriously affected by the hunting. Earlier studies demonstrated that mucosal lesions and haemorrhages in the abomasum could develop after a short period of acute stress. Stressful reindeer herding by means of helicopter in deep snow for 4 hours caused high frequencies of abomasal lesions (Rehbinder *et al*, 1982; Rehbinder, 1990). From the present study, however, we can conclude from the measured values of blood metabolites and abomasal lesions that herding by helicopter was not so stressful to the reindeer that it affected the homeostasis of the animals, whereas the manual handling

Table 5. Sensory evaluation scores for meat (*M. longissimus*) (least-squares means and standard errors) from reindeer bulls in groups A, B, C and G included in the study and the degree of significance for the effect of treatment group, $n$=4 in each group.

| Attribute | *Treatment group* A No handling | B Before selection | C After selection | G Herded by helicopter 3 days | Std. error | Degree of sign.[1)] |
|---|---|---|---|---|---|---|
| Intensity of odour | 3.8[a] | 5.8[b] | 6.9[bc] | 7.3[c] | 0.39 | *** |
| Liver odour | 4.1[a] | 2.9[b] | 2.0[bc] | 1.8[c] | 0.29 | *** |
| Pungent odour | 1.4[a] | 4.4[b] | 6.1[bc] | 6.7[c] | 0.63 | *** |
| Sickeningly sweet odour | 1.9[a] | 3.7[b] | 4.2[bc] | 4.9[c] | 0.28 | *** |
| Whiteness | 3.9[a] | 4.5[b] | 4.6[b] | 4.3[b] | 0.08 | *** |
| Hue | 4.3[a] | 4.9[b] | 5.3[c] | 4.7[ab] | 0.15 | ** |
| Intensity of colour | 3.7[a] | 4.5[b] | 4.9[c] | 4.1[ab] | 0.21 | ** |
| Intensity of flavour | 4.5[a] | 5.9[b] | 6.7[bc] | 7.0[c] | 0.28 | *** |
| Liver flavour | 5.1[a] | 3.5[b] | 2.5[bc] | 2.3[c] | 0.32 | *** |
| Sharp flavour | 1.3[a] | 4.5[b] | 6.2[c] | 6.4[c] | 0.55 | *** |
| Sickeningly sweet flavour | 1.7[a] | 3.5[b] | 4.2[b] | 4.4[b] | 0.24 | *** |
| Acidic flavour | 5.2[a] | 2.8[b] | 1.8[b] | 1.7[b] | 0.31 | *** |
| Juiciness | 4.5a | 4.7[a] | 4.5[a] | 4.5[a] | 0.12 | n.s. |
| Hardness | 3.8[a] | 4.5[a] | 4.4[a] | 4.5[a] | 0.26 | n.s. |
| Tenderness | 6.4[a] | 5.7[a] | 5.8[a] | 5.7[a] | 0.29 | n.s. |

[1)] n.s.= $P>0.05$; ** = $P\leq0.01$; *** = $P\leq0.001$.

Within-attribute means having the same superscript are not significantly different ($P>0.05$).

and restraint of individual animals during the traditional lasso-selection procedure had a serious impact on the reindeer.

Skeletal muscle lesions have earlier been reported in connection with stressful situations; herding and handling of reindeer (Rehbinder *et al.*, 1982), restraint stress in pigs (Bjurström, 1995), capture of wild white-tailed deer (Beringer *et al.*, 1996) and other wild ruminants (Harthoorn, 1977). In the present study, an evaluation of the extent and severity of degenerative changes was not possible, probably due to the limited sample size and number of samples obtained. Muscular lesions indistinguable from those of capture myopathy were however recorded in all treatment groups.

The present study has confirmed an earlier finding that a 'stress-flavour' could develop in reindeer meat after intensive pre-slaughter handling of the animals, as the groups selected by use of a lasso (C) and herded by helicopter for 3 days (G) had the highest values of pungent odour, sickeningly sweet odour, sharp flavour and sickeningly sweet flavour. It is common knowledge among reindeer herdsmen that animals that have been exposed to very stressful pre-slaughter handling give meat with 'stress-flavour'. This flavour is described as unpleasant, strong - even acrid. Several studies have tried to correlate the concentrations of substances such as putrescine, spermidine, spermine, creatine, creatinine and dimethylamine in reindeer meat and plasma with the presence of 'stress-flavour' in the meat (Rehbinder & Edqvist, 1981; Hanssen *et al.*, 1984; Rogstadkjærnet & Hanssen, 1985; Hanssen & Skei, 1990), but the issue is still unresolved. Liver flavour has been detected in cuts of beef *semimembranosus* muscle following injection with lactic acid and calcium chloride solutions, while non-injected cuts evidenced less of this off-flavour (Eilers *et al.*, 1994). All the cuts had very low pH values, similar to those in group A in the present study, where both the liver flavour and the liver odour were stronger than in all other groups. Storage of cuts for up to 17 days *post mortem* did not affect the intensity of liver flavour in beef (Eilers *et al.*, 1994).

The results from the present study indicated that the traditional selection technique of using a lasso may well be the most stressful and glycogen-depleting handling procedure so far studied. By contrast, a modern technique such as helicopter herding did not negatively affect glycogen content, ultimate pH, the values of the measured blood metabolites or the frequency of abomasal lesions. Further research is definitely needed to thoroughly investigate the selection procedure and to compare the lasso technique with other selection methods.

There is also a need for further research in the field of sensory quality of reindeer meat. It is of great general interest to study when and how a 'stress-flavour' develops in the meat, and also to assess the effects of different feeding regimes, starvation, and extremely protracted transport on the sensory quality of reindeer meat.

The relationship between technological and sensory meat quality characteristics and skeletal muscle lesions in reindeer ought to be further investigated, concerning meat quality as well as animal welfare. From earlier studies (Barnier, 1995; Wiklund *et al.*, 1995) it is known that, in reindeer meat, the post-mortem pH decline is rapid, which is unusual in other investigated ruminants. Further studies of the *post mortem* metabolism and the speed and efficiency of muscle proteolysis in reindeer meat in relation to skeletal muscle degeneration are therefore of great interest.

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