The effects of pre-slaughter selection of reindeer bulls (*Rangifer tarandus tarandus L.*) on technological and sensory meat quality, blood metabolites and abomasal lesions

E. Wiklund*, G. Malmfors & K. Lundström

Swedish University of Agricultural Sciences, Department of Food Science, P. O. Box 7051, S-750 07 Uppsala, Sweden.
e-mail: Eva.Wiklund@lmv.slu.se
*corresponding author.

Abstract: Thirty reindeer bulls (age 1¹/₂ years) were subjected to different pre-slaughter treatments to study the effects on ultimate pH values, muscle glycogen content, blood metabolites and abomasal lesions. Gathering and herding inro a grazing corral were followed by various selection procedures. Before starting these, a control group of 10 reindeer were captured by lasso and slaughtered outside the grazing corral. Ten reindeer were then selected by hand from a small group of animals (100-150 head) in a small selection corral. Another 10 reindeer were selected from a large herd of about 1000-2000 animals, by the traditional technique of using a lasso. During a 6-hour selection, animals were captured and slaughtered after 1.5 hours (*n*=2), 3.5 hours (*n*=2), 5 hours (*n*=3) and 6 hours (*n*=3) respectively. The results showed the technique of using a lasso to be stressful and glycogen-depleting, as the two lasso captured groups (the control group and the reindeer exposed to the protracted lasso selection) had the highest ultimate pH values and lowest muscle glycogen values measured. By contrast, the selection procedure where reindeer were captured by hand, was not found to be detrimental to glycogen content and ultimate pH values. Nevertheless, both selection techniques expose the reindeer ro acute stress during the capture and manual restraint, which in the present study was reflected in high plasma cortisol values in all treatment groups. The frequency of abomasal lesions was highest in the group of reindeer subjected to the prolonged selection procedure. No connection between technological and sensory meat quality was found in this study. The technique of selecting animals by hand ought to be further developed so that existing practical problems can be solved. The technique could then be recommended for wider use.

Key words: pre-slaughter handling, DFD, ultimate pH, muscle glycogen, ASAT, urea, cortisol, stress.

Introduction

The pre-slaughter handling of reindeer is nowadays mostly a modern management procedure which is dependent on mechanical aids such as motorcycles, snowmobiles, helicopters and lorries. All these aids are used during gathering, herding and transportation to slaughter. However, there are also specific and traditional handling procedures involved in the slaughter handling of reindeer, procedures closely associated with Saami culture. One of these procedures is the selection of animals just before slaughter by the use of a lasso (Malmfors & Wiklund, 1996).

The pre-slaughter handling of animals is of great importance for the quality of meat as well as for animal welfare (Warriss, 1993; Gregory, 1996). In

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

Treatment group	Number of bulls	Pre-slaughter handling procedure	Capture and stunning procedure
A	10	Control group. Herded and driven to a grazing corral. Over-night holding in the grazing corral.	Captured by lasso (all 10 reindeer within 30 min). Manually restrained and stunned with a captive bolt outside the grazing corral.
B	10	Same treatment as group A. Then, after the reindeer in group A had been captured and slaughtered, a small group of animals (100-150 head) were transferred from the big herd in the grazing corral, to a small selection corral.	Captured by hand (all 10 reindeer within 10 min) in the antlers or around the neck. Manually restrained and stunned with a captive bolt just outside the selection corral.
C	10	Same treatment as group A. Then, after the reindeer in groups A and B had been captured and slaughtered, the whole hetd (1000-2000 head) was transferred from the grazing corral to a large selection corral.	During a 6-hour selection, animals were captured by lasso after 1.5 hours ($n=2$), 3.5 hours ($n=2$), 5 hours ($n=3$) or 6 hours ($n=3$). Manually restrained and stunned with a captive bolt just outside the selection corral.

reindeer, meat quality traits (ultimate pH values, glycogen content and sensory quality) 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 impair ultimate pH values or glycogen content in the muscles (Wiklund *et al.*, 1995; 1996a; 1996b). The traditional lasso selection technique however was evidently a very stressful and glycogen-depleting handling procedure (Wiklund *et al.*, 1996b). Furthermore, the sensory quality of the meat appeared to be affected by pre-slaughter handling, as a 'stress-flavour' was detected in meat from reindeer subjected to gathering, lasso selection and helicopter herding, whereas this flavour was not detectable in meat from reindeer shot in the mountains.

The purpose of the present investigation was to study and compare the effects of two commonly used pre-slaughter selection procedures for reindeer (by using a lasso or by catching the animals by hand) on technological (ultimate pH and glycogen content) and sensory meat quality. Another objective was to study the effects on stress-induced blood metabolites and pathological changes in the abomasal mucosa after these two pre-slaughter selection procedures.

Material and methods

The study was performed in Mellanbyn, a Saami community close to Gällivare in northern Sweden. A total of 30 reindeer bulls (age $1^{1}/_{2}$ years) were subjected to three different pre-slaughter treatments (Table 1).

The reindeer were stunned with a captive bolt. 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* (LO) (at the last rib), *M. biceps femoris* (BF) and *M. triceps brachii* (TB) were taken no later than 15 min post mortem and frozen in liquid nitrogen.

Blood and muscle samples were taken directly outside the grazing and selection corrals, and the carcasses were then transported by helicopter to the slaughterhouse in Harrå, a distance of about 3 km, where the slaughter procedure was completed.

The abomasal mucosa from all reindeer were examined for the presence of mucosal lesions and haemorrhages and judged on a scale from 0 (not affected) to 4 (severe lesions).
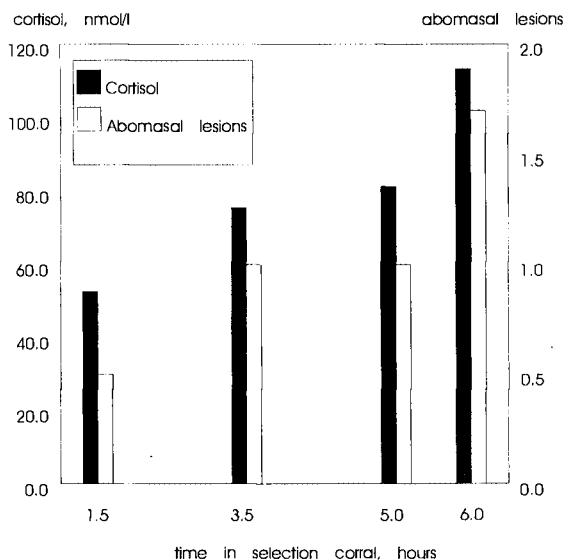
Fig. 1. Plasma cortisol values and abomasal lesions (least-squares means) in reindeer bulls exposed to the traditional lasso selection procedure (treatment group C) for 1 hour (*n*=2), 3.5 hours (*n*=2), 5 hours (*n*=3) or 6 hours (*n*=3).

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 1M HCl (Lowry & Passoneau, 1973).

Blood metabolites
Plasma samples were analysed for aspartate aminotransferase (ASAT), urea and cortisol. ASAT was determined by a kinetic technique on 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 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. The intra-assay coefficients of variation calculated from three control samples were 12.1% (40 nmol/l), 8.1% (86 nmol/l) and 4.5% (543 nmol/l). The corresponding inter-assay coeffi-

cients of variation were 8.3%, 5.2% and 5.6%. The smallest amount of cortisol detectable (defined as intercept of maximum 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 *M. longissimus* (at the last rib), *M. biceps femoris* and *M. triceps brachii* at 24 h *post mortem*.

Sensory evaluation
The carcasses were chilled for 2 days, after which the saddles (the part of the back which is cut out between *vertebrae thoracales* 6-7 and *vertebrae lumbales* 5-6) were excised and frozen. The saddles were then transported to Matforsk (Norwegian Food Research Institute, Ås, Norway) where the sensory analysis was performed. Each saddle was split in two parts (right and left *M. longissimus*) and sawn into chops. The panel members invariably received their chops from the same part of the *longissimus muscle*. The chops had been vacuumpacked 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 of 10 members, using a descriptive test (Stone & Sidel, 1985; Piggott, 1988). The questionnaire was formulated with particular reference to reindeer meat (Wiklund *et al.*, 1996b). The definitions of the profile attributes are set out in Table 2, and the panel scored the sensoty attributes on a continuous intensity scale ranging from 0 (low intensity) to 9 (high intensity).

Statistical analyses
The statistical analyses were 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). The model for comparing muscle and blood parameters and abomasal lesions included the fixed effect of treatment group. When the sensory attributes of the *longissimus* muscle were compared, the model included the random effect of animal nested within treatment group, as well as the fixed effects of treatment group and panel

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.
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.

member. Interactions between panel members and treatment groups were ignored.

As in earlier studies (Wiklund *et al.*, 1995; 1996a; 1996b) 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, become non-symmetric and error ranges on the pH scale were therefore calculated from the estimated means ± standard errors.

Results

Glycogen content and ultimate pH values
The group of reindeer selected by hand (B) had the significantly highest content of glycogen in *Mm. longissimus, biceps femoris* and *triceps brachii* (Table 3).

The ultimate pH values measured in *Mm. longissimus* and *biceps femoris* in the lasso selected group (C) were significantly higher than in reindeer selected by hand (group B) (Table 3). In *M. triceps brachii*

there were no differences in ultimate pH between groups.

Blood metabolites and abomasal lesions
The group of reindeer traditionally selected by lasso from a large herd of animals during 6 hours (C) showed the highest ASAT values in comparison with the other two groups (Table 4). The urea values of the control group (group A) were significantly lower than in the selected groups (groups B and C). Cortisol values were high in all groups, but the selected groups (B and C) had the highest values in comparison with the control group (A). During the ptotracted selection (group C) there was a trend of increasing cortisol values and after 6 hours of running in the selection corral, the highest values were recorded (Fig. 1). When investigating the abomasal mucosa it was found that the lasso selected group (C) had most lesions, and during the selection in this group there was a tendency of an increase in the frequency of lesions so that after 6 hours of running the highest values were registered (Fig.1).

Table 3. Glycogen content and ultimate pH value in *M. longissimus*, *M. biceps femoris* and *M. triceps brachii* (least-squares means (srandard errors[1]) for reindeer bulls included in the study, $n=10$ in each group.

Trait	Treatment group			
	A Control group	B Captured by hand	C Captured by lasso after 1.5 to 6 hours	Standard error
Glycogen, mmol/kg dry weight				
M. longissimus	115[a1]	176[b1]	100[a1]	22.7
M. biceps femoris	136[a1]	193[b1]	105[a1]	22.7
M. triceps brachii	99[a1]	151[b1]	85[a1]	22.7
pH value1				
M. longissimus	5.72[ab1] 5.68-5.7	5.63[b1] 5.59-5.67	5.86[a1] 5.80-5.92	
M. biceps femoris	5.76[ab1] 5.72-5.82	5.62[b1] 5.59-5.66	5.97[a1] 5.90-6.05	
M. triceps brachii	5.94[a1] 5.87-6.02	5.83[a2] 5.77-5.87	6.11[a1] 6.01-6.23	

[1] For pH, 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 nor significantly different $(P>0.05)$.

Sensory evaluation
Significant inter-group differences were found regarding odour, colour and flavour attributes. Meat from reindeer in the control group (A) had a stronger intensity of odour, compared with the lasso selected group (C). The control group also had a stronger, more pungent odour than the other groups. In the group selected by hand (B), the meat had a slightly darker colour than in the other groups, and also had a more acidic flavour, compared with control group.

Discussion

In this study it was clearly demonstrated that the pre-slaughter selection techniques variously affected the ultimate pH values of the meat and the muscle glycogen stores. Though all the 10 reindeer in group A were captured by lasso within 30 min, their muscle glycogen values were very low in all muscles studied (*Mm. longissimus, biceps femoris* and *triceps brachii*) and indistinguishable from those of reindeer in group C which were traditionally selec-

ted by lasso during 6 hours. Our earlier studies showed that glycogen stores were not depleted when reindeer were transported by lorry for distances up to 1000 km or when kept in lairage for 2 days with access to hay and water (Wiklund *et al.*, 1996a). Herding by helicopter for 1, 2 and 3 days respectively did not deplete muscle glycogen stores, whereas the traditional lasso selection procedure was indicated to be a stressful and glycogen-depleting event (Wiklund *et al.*, 1996b). Manual handling and restraint have been found to cause severe muscle glycogen depletion in reindeer (Essén-Gustavsson & Rehbinder, 1984). The results of the present study showed that the reindeer is particularly sensitive to the restraint stress implicated in handling procedures where the lasso is used.

Reindeer meat has earlier been reported to have extremely high ultimate pH values and low glycogen content, qualities associated with DFD (dark, firm, dry) meat, which is a well-known meat quality defect (Petäjä, 1983; Wiklund *et al.*, 1995). DFD meat has a shorter shelf life, especially if the meat is vacuum-packed, therefore it is a 'rule of thumb' in

the meat industry that any fresh meat with a pH value of 5.9 or more is not vacuum-packed (Zeuthen & Mead, 1996). The Swedish slaughter industry nowadays usually applies a DFD limit of 5.8 for the *M. longissimus* in beef carcasses. Had this limit been applied in the present study, 12 carcasses of the total of 30 (4 from group A, 1 from group B and 7 from group C) would have been classified as DFD.

The results published from earlier studies where various shoulder muscles in reindeer were found to have higher ultimate pH values compared with the *longissimus* muscle (Skjenneberg *et al.*, 1974; Petäjä, 1983; Wiklund *et al.*, 1995; 1996b), could only be confirmed in the present study when the reindeer were selected by hand (group B). The present results might be attributable to the way in which physical force is applied to a lasso-captured reindeer. The animal expends much of its muscular strength during the fight and struggle when captured and dragged out of the selection corral. Most of the muscles will therefore become more or less glycogen depleted and produce meat with high ultimate pH values.

The plasma ASAT and urea values measured in the present study were fairly low and stable, compared with earlier studies on reindeer where these blood metabolites were used as markers for catabolism of protein due to submaintenance energy intake or to stress (Hyvärinen *et al.*, 1976; Nieminen, 1980; Wiklund *et al.*, 1996b). In earlier studies, plasma cortisol content has been used as a marker for acute stress in veal calves (Trunkfield & Broom, 1990; Trunkfield *et al.*, 1991), cattle (Eichinger *et al.*,

1991) and reindeer (Rehbinder *et al*, 1982; Wiklund *et al.*, 1994). The cortisol values measured in the present study were high in all groups. Mucosal lesions and haemorrhages in the abomasum as a result of acute stress, have earlier been demonstrated in reindeer (Rehbinder, 1990; Wiklund *et al.*, 1996b). In the present study, the frequency of abomasal lesions was highest in the lasso-selected group (C), and during the 6 hours of selection the frequency increased, actually synchronized with the cortisol values (Fig. 1). In the present study we could conclude from the measured values of blood metabolites and abomasal lesions that the sudden stress caused by capture and restraint affected reindeer in all three groups, but that the protracted lasso selection procedure (group C) had the most serious impact on reindeer homeostasis.

A certain 'stress-flavour' has earlier been described in reindeer meat from animals exposed to intensive pre-slaughter handling (Rehbinder & Edqvist, 1981; Wiklund *et al*, 1996b). The results of the present sensory evaluation revealed very few differences between the treatment groups, though meat from reindeer in the control group (A) had the highest values of pungent odour (one of the qualities associated with the concept 'stress-flavour'). The individual variation among animals to develop a 'stress-flavour' and other off-flavours in the meat might explain this phenomenon. Furthermore, meat from the group selected by hand (B) tended to have high values of liver odour, liver flavour and also of acidic flavour. The latest results are consistent with earlier reports on beef (Eilers *et al.*, 1994) and

Table 4. Blood metabolites and abomasal lesions (least-squares means ± standard errors) in reindeer bulls included in the study and the degree of significance for the effect of treatment group, $n=10$ in each group.

Trait	Treatment group			Standard error	Degree of significance[1]
	A Control group	B Captured by hand	C Captured by lasso after 1.5 to 6 hours		
ASAT, µkat/l	1.4[a]	1.4[a]	1.7[b]	0.1	***
Urea, mmol/l	5.0[a]	6.9[b]	6.7[b]	0.5 - 0.6	*
Cortisol, nmol/l	67.9[a]	92.6[b]	84.0[b]	6.0	*
Abomasal lesions	0[a]	0.2[a]	1.1[b]	0.1	***

1 * = $P \leq 0.05$; *** = $P \leq 0.001$.
Within-trait means having the same superscript are not significantly different ($P > 0.05$).

Table 5. Sensory evaluation scores in meat (*M. longissimus*) (least-squares means and standard errors) from reindeer bulls included in the study and the degree of significance for the effect of treatment group, $n=10$ in each group.

| Attribute | Treatment group | | | Standard error | Degree of sign.[1] |
	A Control group	B Captured by hand	C Captured by lasso after 1.5 to 6 hours		
Intensity of odour	6.2[a]	6.0[ab]	5.9[b]	0.08	*
Liver odour	3.1	3.4	3.3	0.10	n.s.
Pungent odour	4.2[a]	3.6[b]	3.6[b]	0.13	**
Sickeningly sweet odour	3.2	3.1	3.1	0.08	n.s.
Whiteness	4.9[ab]	4.8[a]	4.9[b]	0.05	*
Hue	5.1	5.1	5.1	0.11	n.s.
Intensity of colour	4.6	4.6	4.7	0.12	n.s.
Intensity of flavour	6.1	6.1	6.0	0.04	n.s.
Liver flavour	4.4	4.7	4.3	0.21	n.s.
Sharp flavour	3.8	3.5	3.6	0.12	n.s.
Sickeningly sweet flavour	3.1	3.0	3.1	0.11	n.s.
Acidic flavour	3.8[a]	4.1[b]	3.8[ab]	0.12	*
Juiciness	4.9	5.0	5.0	0.08	n.s.
Hardness	3.2	3.0	3.0	0.22	n.s.
Tenderness	6.9	7.1	7.0	0.25	n.s.

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

reindeer (Wiklund *et al.*, 1996b) where a relationship between low ultimate pH values and liver flavour in the meat was found.

The results from the present study confirmed earlier findings that the traditional selection technique of using a lasso was the most stressful and glycogen-depleting pre-slaughter handling procedure for reindeer so far studied. Another commonly used selection procedure, where the animals are selected by hand, was shown to subject the reindeer to a short period of acute stress, but was not to be detrimental to ultimate pH values and muscle glycogen content. This selection technique ought to be further developed so that existing practical problems can be solved (e.g. during the early autumn slaughter of adult bulls, this technique can be dangerous as regards labour protection), and thereafter the technique could be recommended for more general use.

There is still a need for further research in the field of sensory quality of reindeer meat. The phenomenon 'stress-flavour' *per se* ought to be further investigated and explained chemically. Stress-flavour also needs to be investigated in meat from reindeer given supplementaty feeding, and exposed to protracted lorry transport and pre-slaughter lairage at the slaughterhouse, in order to assess the effects of these handling routines on the sensory quality the meat. The importance of individual variation among animals to develop various off-flavours in the meat should also be investigated. The considerable variation in the diet and nutritional status of reindeer over the year ought to be studied regarding the sensory quality of the meat from reindeer slaughtered at various seasons of the year.

References

Eichinger, H. M., Goldberg, M., Krieglstein, B., Roiger, S., Amann, B. & Beck, G. 1991. Antemortem stress and the variance of blood metabolites, cortisol and catecholamines in cattle. – *In: Proceedings: 37th International Congress of Meat Science and. Technology, Kulmbach, Germany,* pp. 229–232.

Eilers, J. D., Morgan, J. B., Martin, A. M., Miller, R. K., Hale, D. S., Acuff, G. R. & Savell, J. W. 1994. Evaluation of calcium chloride and lactic acid injection on chemical, microbiological and descriptive attributes of mature cow beef. – *Meat Science* 38: 443–451.

Essén-Gustavsson, B. & Rehbinder, C. 1984. The influence of stress on substrate utilization in skeletal muscle fibres of reindeer (*Rangifer tarandus* L). – *Rangifer* 4 (1): 2–8.

Gregory, N. G. 1996. Welfare and hygiene during pre-slaughter handling. – *Meat Science* 43S: S35–S46.

Hyvärinen, H., Helle, T., Nieminen, M., Väyrynen, P. & Väyrynen, R. 1976. Some effects of handling reindeer during garherings on the composition of their blood. – *Anim. Prod.* 22: 105–114.

Lowry, O. H. & Passoneau, J. V. 1973. *A Flexible System for Enzymatic Analysis.* Academic Press, New York.

Malmfors, G & Wiklund, E. 1996. Pre-slaughter handling of reindeer – effects on meat quality. – *Meat Science* 43S: S257–S264.

Nieminen, M. 1980. *The composition of reindeer blood. in respect to age, season, calving and. nutrition.* Dissertation, Department of Zoology and department of Physiology, University of Oulu, Finland.

Petäjä, E. 1983. DFD meat in reindeer meat. – In: *Proceedings: 29th European Congress of Meat Research Workers, Salsomaggiore, Italy,* pp.117–124.

Piggott, J. R. 1988. *Sensory Analysis of Foods.* Elsevier Applied Science, New York.

Rehbinder, C. 1990. Management stress in reindeer. – *Rangifer* Special Issue No. 3: 267–288.

Rehbinder, C. & Edqvist, L-E. 1981. Influence of stress on some blood constituents in reindeer (*Rangifer tarandus* L). – *Acta Vet. Scand.* 22: 480–492.

Rehbinder, C., Edqvist, L-E., Lundström, K. & Villafañe, F. 1982. A field study of management stress in reindeer (*Rangifer tarandus* L). – *Rangifer 2* (2): 2–21.

SAS Institute. 1995. *SAS system for Windows, release* 6.11. SAS Institute Inc., Cary, NC.

Skjenneberg, S., Jacobsen, E. & Movinkel, H. 1974. pH-verden i reinkjøtt etter forskjellig behandling av dyrene for slakting. – *Nordisk veterinärmedicin* 26: 436–443.

Stone, H. & Sidel, J. L. 1985. Sensory Evaluation Practices. Academic Press, New York.

Trunkfield, H. R. & Broom, D. M. 1990. The welfare of calves during handling and transport. – *Appl. Animal Behaviour Sci.* 28: 135–152.

Trunkfield, H. R., Broom, D. M., Maatje, K., Wierenga, H. K., Lambooy, E. & Kooijman, J. 1991. Effects of housing on responses of veal calves to handling and transport. – *In:* Metz, J. H. M. & Groenestein, C. M. (eds.). *New Trends in Veal Calf Production.* Pudoc, Wageningen, The Netherlands, pp. 40–43.

Warriss, P. D. 1993. Ante-mortem factors which influence carcass shrinkage and meat quality. – *In: Proceedings: 39th International Congress of Meat Science and. Technology, Calgary, Canada,* pp. 51–65.

Wiklund, E., Andersson, A., Malmfors, G. & Lundström, K. 1996a. Muscle glycogen levels and blood metabolites in reindeer (*Rangifer tarandus tarandus* L) after transport and lairage. – *Meat Science* 42: 133–144.

Wiklund, E., Andersson, A., Malmfors, G., Lundström, K. & Danell, Ö. 1995. Ultimate pH values in reindeer meat with particular regard to animal sex and age, muscle and transport distance. – *Rangifer* 15: 47–54.

Wiklund, E., Goddard, P. J. & Rehbinder, C. 1994. Remote blood collection in reindeer (*Rangifer tarandus tarandus* L): a preliminary study. – *Rangifer* 14: 29–32.

Wiklund, E., Malmfors, G., Lundström, K. & Rehbinder, C. 1996b. Pre-slaughter handling of reindeer bulls *(Rangifer tarandus tarandus* L.) – effects on technological and sensory meat quality, blood metabolites and muscular and abomasal lesions. – *Rangifer* 16: 109–117.

Zeuthen, P. & Mead, G. C. 1996. Microbial spoilage of packaged meat and poultry. – *In:* Taylor, S. A., Raimundo, A., Severini, M. & Smulders, F. J. M. (eds.). *Meat Quality and. meat packaging.* ECCEAMST, Utrecht, The Netherlands, pp. 273-283.