Sensory meat quality, ultimate pH values, blood metabolites and carcass parameters in reindeer (*Rangifer tarandus tarandus* L.) fed various diets

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Abstract: This investigation was made to study and compare the effects of different diets on sensory meat quality and ultimate pH values in reindeer muscles and to relate stress-induced blood metabolites and carcass parameters to the meat quality traits measured. Altogether 23 female reindeer calves were included in the study. During an adaptation period, all reindeer were allowed free access to a mimicked natural diet containing 80% lichens (lichen diet). On January 28, 8 reindeer (group C_{Jan}) were slaughtered. Five reindeer (group C_{Mar}) were allowed continuous free access to the lichen diet throughout the experiment. During 8 days, the other reindeer (groups PL and PS) were given the lichen diet, half of the amount offered to the control group, and were then starved for one day. Thereafter, these reindeer were fed 80% commercial reindeer feed (pellets) and either 20% lichens (group PL), or 20% silage (group PS) for 5 weeks. After this, all animals were slaughtered. The average carcass weight and dressing percentage in the group fed commercial reindeer feed and lichens (PL) were higher than in group C_{Mar}. Fat registrations were generally higher in groups PL and PS than in the groups C_{Jan} and C_{Mar}. Ultimate pH values in *M. triceps brachii* and *M. longissimus* were significantly lower in the group C_{Mar} than in PL. The levels of all blood metabolites (urea, ASAT and cortisol) were generally higher in groups PL and PS than in groups C_{Jan} and C_{Mar}. No significant differences were found in any of sensory attributes of the meat (monitored according to ISO standards). The present study shows that muscle and fat depots in reindeer can be improved by feeding a diet based on reindeer pellets but suggests that a feeding period of 35 days might be too short to affect the sensory properties of reindeer meat.

Key words: meat, ultimate pH, ASAT, urea, cortisol, carcass quality, sensory quality.

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Introduction

Reindeer husbandry is generally based on the utilization of native pastures and reindeer normally obtain all the nutrients they need from vegetation growing on these pastures. Nevertheless at times, reindeer are fed during the winter to prevent starvation or to improve body weight and condition. In some areas, feeding is used as a countermeasure to reduce radioactive caesium in the reindeer (Åhman, 1999). The animals are either fed in the field or brought into a corral and fed there for a period of up to 3 months. Commercial feed mixtures, specially prepared for reindeer, are commonly used in combination with hay, grass silage or lichens.

The feeding of a commercial mixture to reindeer for two months has been shown to improve the nutritional status, increase muscle glycogen stores and reduce the concentration of certain blood metabolites used as markers for protein catabolism or stress (Wiklund *et al*, 1996a). In animals in good physical condition, the muscles contain enough glycogen to guarantee optimal ultimate pH values in the meat. Meat with high ultimate pH values (dark-cutting or Dark, Firm, Dry) is a persistent quality defect that shortens shelf life, especially for vacuum-packed meat (Gill & Newton, 1981), and affects meat colour, texture and water-holding properties (Hood & Tarrant, 1981). Like other Nordic cervides, reindeer are known to have a low capacity to gain weight during winter, vis-á-vis summer (White & Fancy, 1986). It is still possible for reindeer calves to gain between 0.1 and 0.2 kg live weight (0.05-0.10 kg carcass weight) per day when fed mainly commercial reindeer feed (Åhman, 1996; Nilsson *et al*, 1996). The degree of tameness of the animals may also increase as a result of feeding, which may contribute significantly to the animals' ability to tolerate stress (Rehbinder, 1990).

A certain 'stress-flavour' has earlier been described in meat from reindeer exposed to intensive pre-slaughter handling (Rehbinder & Edqvist, 1981; Wiklund *et al*, 1996b; 1997). This observation underlines the importance of investigating the considerable variation in diet and nutritional status of reindeer regarding the sensory quality of the meat.

The purpose of the present investigation was to study and compare the effects of three different diets, one resembling a natural diet, while the other two were diets commonly used in reindeer husbandry, on sensory meat quality and ultimate pH values in reindeer muscles. Another objective was to relate stress-induced blood metabolites and carcass parameters in reindeer fed the different diets to the measured meat quality traits.

Material and methods

This study, performed at the University of Oulu, Finland, was part of a larger experiment (Nilsson *et al*, submitted). A total of 23 female reindeer (*Rangifer tarandus tarandus*) calves were included in the present study. The reindeer originated from five different herding groups (Paliskunta) in the southern part of the Finnish reindeer herding area. They were brought to the university between November 12, 1996, and January 7, 1997. During the period from arrival until January 27 (adaptation period), all the animals were given free access to a mixed diet of lichens (*Cladina* spp.) (80%), bilberry brushwood (*Vaccinium myrtillus*) (10%) and willow leaves (*Salix* spp.) (10%), with an estimated content of 4.8% crude protein (CP) and 10.5 MJ metabolizable energy (ME) per kg dry matter. On January 28, eight randomly allotted reindeer (group C_{Jan}) were slaughtered. The remaining reindeer were allotted into three groups, 5 reindeer to each group. The animals were kept in outdoor pens throughout the experiment and housed together with 8 other reindeer per pen.

A control group (C_{Mar}) was continuously given free access to the lichen diet throughout the experiment. From January 28 to February 4 (restriction period), the other two groups (PL and PS) were given the lichen diet, but only half of the amount offered to the control group, and were thereafter starved for one day (February 5). From February 6 (feeding period), the reindeer in group PL were fed a diet of 80% commercial reindeer feed (reindeer pellets) and 20% lichens (with 8.6% CP and 10.1 MJ ME per kg dry matter), while the reindeer in group PS were fed a diet of 80% pellets and 20% silage (with 12% CP and 10.0 MJ ME per kg dry matter). The reindeer feed used was a commercial pelleted feed (Renfor Bas, Lantmännen Fori, Holmsund, Sweden) based on oat, wheat and bran products, sugar beet pulp and soybean meal. The feed ration was gradually increased during the first week of the feeding period and after one week all groups were offered free access to their diets. The animals were fed twice a day and the diets were mixed in the cribs. All reindeer had free access to water (about 10 °C) during the experiment. The reindeer were taken out of the pens once a week throughout the experiment for blood sampling and body weight measuring. After the feeding period (35 days) all animals were slaughtered, group C_{Mar} on March 11 and groups PL and PS on March 12.

Sampling

Blood samples were taken on the day of slaughter from group C_{Jan}, one day before slaughter from group C_{Mar} and 2 days before slaughter from groups PL and PS. At sampling, the reindeer were taken out of their pens, individually restrained in a treatment chair and blood sampled via the *vena jugularis*. The blood samples were collected in heparinized tubes, chilled, centrifuged and the plasma was

frozen and stored at -20 °C. Live body weight was measured on the day of slaughtet, before the reindeer were transported by lorry to the abattoir.

Slaughter routines
The animals were transported for about 30 min on a lorry to the abattoir and slaughtered within 90 min of arrival. They were stunned with a captive bolt. Upon exsanguination (immediately after stunning), blood samples were collected in heparinized tubes and treated as samples from live reindeer above. The abdomen was cut open and the stomachs were collected and weighed. Kidney fat, fat in omentum and carcass weight were recorded. Trim fat was estimated visually according to the EUROP carcass grading system.

pH measurements
Ultimate pH was measured 24 h *post mortem* 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.*

Blood parameters
Plasma samples were analysed for aspartate aminotransferase (ASAT) activity, urea and cortisol concentration. 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 an enzymatic colorimetric test (UREA liquicolor, Human Gesellschaft für Biochemica und Diagnostica mbH, Taunusstein, Germany). Cortisol was assayed by radioimmunoassay (Coat-A-Count®, Diagnostic Products Corporation, Los Angeles, USA). The assay was validated for reindeer plasma in our laboratory.

Sensory evaluation
The saddle (the part of the back which is cut out between *vertebrae thoracales* 6-7 and *vertebrae lumbales* 5-6) from each of 18 reindeer (4 or 5 per group, see Table 4) was excised and packed in a plastic bag and frozen (-20 °C), 2 days *post mortem.* The samples were then transported to the Department of Domestic Sciences (Uppsala University) where the sensory analysis was performed. Upon thawing, the samples were put in a refrigerator at +2 °C for 18 h. The meat was cooked in a conventional oven at 150 °C to a core temperature of 68 °C. The sensory profile of the meat was assessed by 9 panel-members, selected, trained and monitored according to ISO standard (ISO 8586-1, 1993). A modified descriptive test was applied (ISO 6564, 1985) and performed in separate booths under white light according to ISO standard (ISO 8589, 1988). The measured attributes were tenderness, juiciness, reindeer flavour, liver flavour, bitter flavour, sweet flavour and other off-flavours. The panel scored the sensory attributes on a continuous line scale ranging from 0 (low intensity) to 100 (high intensity).

Statistical analyses
The statistical analyses were carried out according to the Statistical Analysis System (SAS Institute Inc., 1997) 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 and muscle). The model for comparing blood metabolites and carcass parameters included the fixed effect of treatment group. When the sensory attributes of the *longissimus* muscle were compared, the model included the random effects of panel member and animal nested within treatment group, as well as the fixed effect of treatment group. Interactions between panel members and treatment groups were ignored.

As in earlier studies (Wiklund *et al*, 1995; 1996a; 1996b; 1997), 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

Live weight and carcass parameters
No significant differences in live weight were found between any of the groups (Table 1). Carcass weights in the groups slaughtered in March (C_{Mar}, PL and PS) did not differ significantly from the group slaughtered in January (C_{Jan}). The average carcass weight and dressing percentage in the group fed commercial reindeer feed and lichens (PL) were, however, significantly higher than in the control

Table 1. Live weight at slaughter and carcass parameters of the reindeer included in the study (least-squares means ± standard errors).

Trait	C_{Jan} (n = 8)	C_{Mar} (n = 5)	PL (n = 5)	PS (n = 5)
Live weight, kg	44.7 ± 1.4	42.0 ± 1.7	44.9 ± 1.7	41.2 ±1.7
Carcass weight, kg	20.6^{ab} ± 0.8	19.5^{a} ± 1.1	23.3^{b} ± 1.1	20.3^{ab} ± 1.1
Dressing percentage	46.0^{a} ± 1.2	46.4^{a} ± 1.5	51.8^{b} ± 1.5	49.4^{ab} ± 1.5
Trim fat, % of carcass weight	2.0^{a} ± 0.4	3.6^{b} ± 0.5	4.8^{bc} ± 0.5	5.2^{c} ± 0.5
Kidney fat, g	6.8^{a} ± 12.2	12.2^{a} ± 15.5	78.6^{b} ± 15.5	36.4^{ab} ± 15.5
Fat in omentum, g	6.8^{a} ± 7.3	18.4^{a} ± 18.2	80.6^{b} ± 18.2	42.0^{ab} ± 18.2

Within rows, mean values marked with the same letter in the superscript are not significantly different (P>0.05).

group (C_{Mar}). The fat registrations (trim fat, kidney fat and fat in omentum) were generally higher in the two groups fed commercial reindeer feed (PL and PS) than in the control group (C_{Mar}) and the group slaughtered in January (C_{Jan}).

Ultimate pH values and blood metabolites

The ultimate pH values in *M. triceps brachii* and *M. longissimus* were significantly lower in group C_{Mar} than in PL, while in *M. biceps femoris* there was no difference in pH values between the groups (Table 2). There were no significant differences in ultimate pH values between the three muscles in any of the treatment groups (Table 2). Urea concentrations were considerably higher in groups PL and PS than in groups C_{Jan} and C_{Mar} (Table 3). Also ASAT activities were slightly higher in groups PL and PS. Urea concentrations did not differ between the two sampling occasions, while ASAT activities in groups PL and PS were higher at slaughter than before slaughter. Cortisol concentrations in group C_{Jan} before slaughter were lower than in the other groups, the difference was significant compared to group PL. At slaughter, the cortisol concentrations were lower in groups C_{Jan} and C_{Mar}, and the difference was statistically significant compared with PS. Cortisol concentrations were significantly higher at slaughter than before slaughter in all groups except C_{Mar}.

Sensory evaluation

There was no significant difference between the groups in any of the measured sensory attributes (Table 4). However, the assessors generally used more words to describe the attribute 'other off-flavours' in groups C_{Jan} and C_{Mar} compared with PL and PS.

Discussion

Grazing reindeer do not normally gain weight during winter (Reimers, 1983) and they seem to have a low appetite during the winter period, compared with summer (Ryg & Jacobsen, 1982). A main reason for weight loss or lack of growth in winter is, however, lack of nutrients. Feeding may therefore help to improve the nutritional status of reindeer (Jacobsen *et al*, 1977).

In the present study there was no weight gain from January to March in the group fed the lichen diet (Nilsson *et al*, submitted). The energy content

Table 2. Ultimate pH values in *M. triceps brachii, M. longissimus* and *M. biceps femoris* (least-squares means ± standard errors[1]) for reindeer included in the study.

Trait	C_{Jan} (n = 8)	C_{Mar} (n = 5)	PL (n = 5)	PS (n = 5)
pH value[1]				
M. triceps brachii	5.80^{ab} (5.76 - 5.85)	5.73^{a} (5.68 - 5.78)	5.91^{b} (5.85 - 5.99)	5.88^{ab} (5.82 - 5.95)
M. longissimus	5.70^{ab} (5.67 - 5.74)	5.62^{a} (5.59 - 5.66)	5.80^{b} (5.74 - 5.85)	5.72^{ab} (5.68 - 5.77)
M. biceps femoris	5.77 (5.73 - 5.81)	5.72 (5.68 - 5.77)	5.81 (5.76 - 5.87)	5.79 (5.74 - 5.84)

[1] Least-squares means and ranges for means ± srandard errors were reconverted from the concentration scale.
Within rows, mean values marked with the same letter in the superscript are not significantly different (P>0.05).

Table 3. Blood metabolites (least-squares means ± standard errors) in reindeer included in the study

Trait	C_{Jan} (n = 8)	C_{Mar} (n = 5)	PL (n = 5)	PS (n = 5)
Live samples				
Urea, mmol/l	$3.1^{a} \pm 0.5$	$2.5^{a} \pm 0.7$	$7.6^{b} \pm 0.7$	$8.4^{b} \pm 0.7$
ASAT, µkat/l	$1.0^{a} \pm 0.1$	$0.9^{a} \pm 0.1$	$1.3^{b} \pm 0.1$	$1.1^{ab} \pm 0.1$
Cortisol, nmol/l	$36.0^{a} \pm 9.8$	$63.1^{ab} \pm 12.5$	$76.9^{b} \pm 12.5$	$56.0^{ab} \pm 12.5$
At slaughter				
Urea, mmol/l	$3.8^{a} \pm 0.6$	$1.7^{b} \pm 0.7$	$8.0^{c} \pm 0.7$	$9.7^{c} \pm 0.7$
ASAT, µkat/l	$1.1^{a} \pm 0.1$	$1.1^{a} \pm 0.1$	$1.9^{b} \pm 0.1$	$1.5^{c} \pm 0.1$
Cortisol, nmol/l	$67.0^{a} \pm 12.8$	$66.7^{a} \pm 16.2$	$108.4^{ab} \pm 16.2$	$152.7^{b} \pm 16.2$

Within rows, mean values marked with the same letter in the superscript are not significantly different (P>0.05).

in the lichen diet should have been sufficient to meet the requirements of the animals. An indicator of this was that the plasma urea concentrations observed in this group were low and did not indicate malnutrition and degradation of muscle tissue. Raised urea concentrations has been reported as an indication of catabolism of proteins due to undernutritional intake of energy (Hyvärinen *et al.*, 1976). The lack of weight gain in the lichen fed group could, however, be explained by the low protein content of the diet that did not allow muscle growth. Reindeer fed the commercial feed mixture (groups PL and PS) all gained weight and were able to increase their fat depots. The high plasma urea concentrations in these groups, compared to the lichen fed groups, is probably and effect of the relatively high intake of protein. A positive correlation between protein intake and plasma urea in reindeer has been shown by e.g. Valtonen (1979), who concluded that blood urea concentrations reflected the alterations in dietary protein intake, but only when the energy intake is sufficient. As discussed above muscle degradation may also result in high plasma urea levels. The present study has confirmed previous findings that reindeer fed the type of commercial feed mixture used here generally improve their nutritional status (Wiklund *et al.*, 1996a; Åhman, 1996), whereas reindeer fed lichens do not gain weight and may even suffer a reduction in nutritional status (Jacobsen & Skjenneberg, 1975; Nieminen *et al.*, 1987).

The pre-slaughter handling of animals has a significant effect on the quality of meat, as well as implications for animal welfare (Gregory, 1996; Goddard, 1998). In earlier studies on reindeer, helicopter herding, lorry transport and lairage at the abattoir did not significantly impair ultimate pH values or glycogen content in the muscles (Wiklund *et al.*, 1995; 1996a; 1996b; 1997). The traditional lasso selection technique however, can evidently be a very stressful handling procedure and cause glycogen depletion (Essén-Gustavsson & Rehbinder,

Table 4. Sensory evaluation scores in meat (*M. longissimus*) (least-squares means ± standard errors) from reindeer included in the study; none of the listed scores differed significantly between groups

Attribute	C_{Jan} (n = 5)	C_{Mar} (n = 4)	PL (n = 5)	PS (n = 4)
Tenderness	71.3 ± 6.4	62.7 ± 7.1	61.4 ± 6.4	56.2 ± 7.1
Juiciness	68.8 ± 5.5	60.5 ± 6.1	65.7 ± 5.5	63.3 ± 6.1
Reindeer flavour	45.7 ± 2.5	43.3 ± 2.7	47.5 ± 2.5	48.5 ± 2.7
Liver flavour	19.8 ± 5.4	24.5 ± 5.9	19.4 ± 5.4	27.6 ± 5.9
Bitter flavour	40.2 ± 4.3	35.2 ± 4.9	41.4 ± 4.5	36.4 ± 4.9
Sweet flavour	16.9 ± 2.1	18.6 ± 2.3	17.5 ± 2.1	19.3 ± 2.3
Other off-flavours[1]	15.7 ± 2.6	14.4 ± 3.3	17.0 ± 2.9	18.3 ± 3.3

[1] The words used to describe this attribute were: iron, blood, acidic, metal, sharp and lamb/sheep.

1984; Wiklund *et al.*, 1996b; 1997). In the present study it was found that, despite a poorer nutritional status, the lichen fed reindeer (C_{Mar}) had significantly lower ultimate pH values (more glycogen stored in their muscles) in *Mm. triceps brachii* and *longissimus* compared with one of the groups fed commercial reindeer feed (PL). The PS group also tended to have higher pH values, compared with C_{Mar} in the same muscles, though the difference was not statistically significant. This indicates that groups PL and PS may have experienced more stress or physical strain than the control group, although the handling of the animals appeared to be the same, and that more of their muscular energy stores therefore had been consumed.

ASAT activities have been shown to increase when reindeer are herded, driven and manually handled (Nieminen, 1980; Rehbinder *et al.*, 1982) and higher levels indicate muscle degeneration. ASAT activities found in the present study, both in live samples and in samples taken at slaughter, were comparable with levels found in totally unstressed reindeer (Rehbinder *et al.*, 1982; Wiklund *et al.*, 1996b) although the levels were higher in groups PL and PS at slaughter than before slaughter. An increase in urea concentration may be seen in connection with stress induced muscular lesions (Essén-Gustavsson & Rehbinder, 1984). The urea concentrations found in this study were the same in live samples and samples taken at slaughter and did not indicate any muscular lesions.

In earlier studies, high cortisol levels 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). From the present results it can be concluded that all reindeer in the experiment were affected by the restraint and sampling. However, there was an increase in cortisol levels in the PL and PS groups when comparing live and slaughter samples, which was not seen in group C_{Mar}, which is another indication of more stress in connection with transport and slaughter in groups PL and PS. No observations were made, however, during the handling of the reindeer that would indicate more stress in these groups, and the duration of handling and transport was the same for all groups. One might speculate that animals in good physical condition have a more active, aggressive and self-assured behaviour, which would make the whole group more troublesome to handle.

There is a common consensus among reindeer herders that the flavour of reindeer meat varies considerably, depending on the pre-slaughter handling technique, seasonal variation in the natural diet, and supplementary feeding using commercial feed mixtures. A so-called 'stress flavour' has been found in meat from intensively pre-slaughter handled reindeer (Hanssen *et al.*, 1984; Wiklund *et al.*, 1996b, 1997), but the phenomenon has not been described or explained chemically (Rehbinder & Edqvist, 1981; Rogstadkjærnet & Hanssen, 1985; Hanssen & Skei, 1990). Brooks & Collins (1984) showed that the meat from reindeer in poor physical condition had an 'undesirable' flavour. Hamilton (1994) refers to the widely differing opinions about perceived flavour differences in meat from farmed versus wild deer, and concludes that a strong gamey flavour in meat from wild deer can sometimes be due to method and duration of storage rather than flavour *per se*. In the present study, no significant differences were found in any of the measured sensory attributes when comparing the treatment groups. The explanation for these results might be that the feeding period was too short (6 weeks) to give detectable changes in meat flavour. However, the panel members used more words to describe the attribute 'other off-flavours' in the control groups, compared with PL and PS, which may indicate a difference in flavour. It cannot be excluded that feeding with a commercial feed mixture for a longer period (normal practice among reindeer herders is at least 8 weeks) will influence meat flavour. The combined use of an expert panel, consumer panel and chemical analyses would make it possible to further study and describe in detail the flavour variation in reindeer meat.

According to a recent questionnaire (SKOP, 1999), most Swedish consumers regarded reindeer meat as tasty, healthy and of good quality. In many reindeer herding systems, it is common practice to feed reindeer for some time in order to improve carcass quality (increase slaughter weights and lean meat content). It is of great interest to further explore how improved carcass quality is related to other meat quality traits and to how the consumer appreciates the meat.

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