Water-holding capacity, colour stability and sensory characteristics in meat (*M. longissimus dorsi*) from reindeer fed two different commercial feeds

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Abstract: Twenty reindeer calves (age 10 months) were included in the study. They were all fed one of two different pelleted feed mixtures *ad libitum* for two months before slaughter. Ten calves were fed a control diet of conventional pellets (CPD) (Renfor Bas, Lantmännen, Holmsund, Sweden) and ten calves received pellets enriched with linseed cake (LPD). The reindeer were slaughtered according to standard procedure at Arvidsjaur Renslakt AB, a reindeer slaughter plant in Arvidsjaur, Sweden. At 1 day *post mortem*, both *longissimus dorsi* (LD) muscles from each carcass were excised. The left LD was used for sensory evaluation and the right LD for colour and water-holding capacity measurements. The right LD was cut in 4 pieces that were randomly allocated to storage times of 1 day, 1, 2, or 3 weeks at + 4 °C. Samples allocated for storage were vacuum packaged. Evaluation of meat colour was carried out after each of the four storage times while drip loss/purge was registered after 1, 2, and 3 weeks storage at + 4 °C. The left LD muscles were vacuum packaged, frozen at -20 °C and kept frozen until preparation for sensory evaluation. No significant differences were found in carcass quality (carcass weight, EUROP carcass conformation and fat scores), meat colour stability and water-holding capacity of LD samples when comparing the two treatment groups LPD and CPD. However, sensory panellists judged samples from LPD fed reindeer to have a tendency (not significant) to be more tender (P= 0.06) and juicy (P=0.07) than the meat samples from CPD fed reindeer. No flavour differences were found when comparing meat samples from the two treatment groups.

Key words: reindeer meat; supplementary feeding; carcass characteristics; sensory evaluation; meat colour; purge.

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Introduction

One of the main reasons to feed reindeer supplements in Sweden is to counteract the radioactive contamination caused by the nuclear accident in Chernobyl in 1986 (Åhman, 1999). The biological half-life of radiocaesium (Cs) has been estimated as 3 weeks. It has been reported that by feeding uncontaminated feed, the levels of ^{137}Cs in reindeer could be reduced by 87 per cent in about two months time (Åhman, 1996). This measure to reduce radioactive contamination in reindeer meat is subsidized by the Swedish State and managed and monitored by the Sami Parliament (Sami Parliament, 2009). According to preliminary figures, there are still 7.2 per cent of all Swedish reindeer intended for slaughter that are fed as a result of the Chernobyl accident 25 years ago (personal communication Sören Långberg

and Rickard Doj, Sami Parliament, 2011). The reindeer are kept and fed in corrals for up to two months (80 days) before slaughter. The most common types of feed used are grain-based pelleted feed mixtures, often in combination with small amounts of grass silage, hay or ground lichens (harvested in geographical areas not contaminated with ^{137}Cs).

Another major reason to feed reindeer is to prevent starvation especially during harsh winter conditions. As an Arctic animal the reindeer is well adapted to a substantial variation and availability of natural pasture. However, periods when pastures are covered by hard snow crust or ice are considered extremely difficult for the animals (Helle, 1984) and in that situation many reindeer herders have no other choice but to feed the reindeer supplementary feed. The reindeer could be fed either out on their natural pastures or brought into fenced corrals and provided the same type of feed as previously described. Finally, there are a few reindeer herders who feed their reindeer to improve meat production. It has been proven difficult to make such feeding economically profitable (Åhman & Danell, 2001). Keeping pastures in good condition by adapting stocking rate to the productivity of the ranges, and optimizing herd structure, are economically much more efficient ways to improve productivity in the reindeer herd than long periods of feeding. The situation is different from an economical point of view when the purpose is to save animals *e.g.* in the case of extreme snow conditions (Åhman & Danell, 2001).

Effects on reindeer meat quality of feeding concentrates, and different types of feeds have been studied. For example, it has been demonstrated that feeding changes the flavour and chemical composition of the meat (Wiklund *et al.*, 2001a; 2003). Meat from pellet fed reindeer had a milder/bland flavour and a higher content of saturated fatty acids compared with meat from grazing animals (Sampels, 2005; Wiklund *et al.*, 2001a; 2003).With the risks of starvation and radioactive contamination as the main reasons, there is an obvious need for a palatable and nutritious supplementary feed for reindeer to be used in such emergency situations. The nutritional composition of this feed should be designed to be similar to the natural diet of reindeer. Grain-based feed mixtures have a higher content of omega-6 fatty acids compared with the natural pasture of the reindeer (Sampels *et al.*, 2005), which is a result of the composition of grains and also of other ingredients in the feed such as added fat (palm- and/or canola oil is common) or palm expeller (rest product from palm oil extraction). In the present study linseed cake was used to substitute other fat sources in a commercially available reindeer pellet (Renfor Bas, Lantmännen, Holmsund, Sweden) to elevate the levels of omega-3 fatty acids in the feed so that the composition of the linseed pellets would be close to that of the natural pasture.

Production systems for reindeer husbandry, where the animals graze during most of the year, are usually considered more animal-friendly and ethical compared with the standard commercial production of beef, pork or poultry. Venison is therefore a product that meets most of the criteria demanded by today's discerning meat consumer (Hoffman & Wiklund, 2006). The introduction of new routines in reindeer husbandry such as intensive farm-based management, industrialised slaughter and meat processing, use of commercial feed mixtures and possibly new ingredients used to supplement or replace pasture will alter reindeer meat quality (Wiklund & Smulders, 2011). One topic of central importance is the image of reindeer meat as a natural, free-range origin, clean and healthy product. Care should be taken to ensure the positive image of reindeer meat as a natural and healthy product is not lost when new production systems are introduced (Wiklund & Smulders, 2011).

Reindeer husbandry, including meat production and processing, is closely linked to the Sami people and their culture and traditions. To strengthen the image of reindeer meat a new quality trade mark, Renlycka, has been developed in Sweden where criteria to measure meat quality (EUROP carcass grading score, meat pH value and natural grazing) are combined with the unique origin and traditional processing of the meat based in the Sami culture (Wiklund *et al.*, 2010a).

The present study completes previous work within the same project. Earlier studies were focusing on the relationship between the nutritional status of the reindeer and nutritional aspects of meat quality by analyzing lipid class composition and intra muscular fat (IMF) content in relation to trim fat, carcass weight and conformation, and by investigating how these parameters were affected by age, sex and feed type (Sampels, 2005; Sampels *et al.*, 2005). The purpose of the present study was to compare the colour stability and water-holding capacity in meat from reindeer fed either normal commercial reindeer pellets or an experimental pellet including linseed cake. In addition, a sensory evaluation of the meat was included.

Material and methods

Animals

Twenty reindeer calves, 10 months old, were included in the study. They were all fed one of two different pelleted feed mixtures *ad libitum* for two months before slaughter. Ten calves were fed a control diet of conventional pellets (CPD) (Renfor Bas, Lantmännen, Holmsund, Sweden) and ten calves received pellets enriched with linseed cake (LPD). Nutrient content of the feeds is presented in Table 1. The pellet-fed reindeer came from the same herd and were kept in feeding corrals at the farm of the reindeer herder (Peter Omma, Hemavan, Ubmeje) in two groups of 50-200 animals during the feeding period. One of these groups was fed LPD pellets while the other group received CPD pellets. The reindeer were slaughtered in early April, according to common procedures at the abattoir (Arvidsjaur Renslakt AB, Arvidsjaur, Sweden). At slaughter, dressed carcass weights were recorded and carcass conformation and trim fat evaluated according to the EUROP-system (Swedish Board of Agriculture, 2002).

Table 1. Nutrient composition of the two feeds used in the study; conventional pellets (CPD) and linseed pellets (LPD). Feed analysis provided by the feed company (Lantmännen, 2011).

Nutrient content	Conventional pellets (CPD)	Linseed pellets (LPD)
Crude protein, %	10.0	10.4
Energy, MJ/kg	10.0	10.0
Fibre, %	15.0	14.6
Crude fat, %	3.0	3.05
Water, %	12.0	12.0
Vitamin A, IU/kg	9000 (2.7 mg/kg)	9000 (2.7 mg/kg)
Vitamin D, IU/kg	3000 (0.075 mg/kg)	3000 (0.075 mg/kg)
Vitamin E, mg/kg	60	60
Calcium, %	0.8	0.8
Phosphorus, %	0.4	0.4
Magnesium, %	0.3	0.3
Selenium, %	0.6	0.6

At 1 day *post mortem*, both *M.longissimus dorsi* (LD) muscles from each carcass were excised. The left LD was used for sensory evaluation and the right LD for colour and water-holding capacity measurements. The right LD was cut in 4 pieces that were randomly allocated to storage times of 1 day, 1, 2, or 3 weeks at + 4 °C. Samples allocated for storage were vacuum packaged. Evaluation of meat colour was carried out after each of the four storage times while drip loss/purge was registered after 1, 2, and 3 weeks storage at + 4 °C. The left LD muscles were vacuum packaged, frozen at -20 °C and kept frozen until preparation for sensory evaluation.

Measurements of pH, meat colour and water-holding capacity

For calibration of the pH equipment, buffers of pH 7.0 and 4.0 (TPS Pty. Ltd., Brisbane, Australia) at room temperature were used. Ultimate pH values and temperatures in LD muscles (LD, at the last rib) were measured at boning using a portable pH meter (Knick Elektronische Messgeräte GmbH & Co, Germany) equipped with a Xerolyte electrode (InLab®427, Mettler Toledo, Switzerland) and a digital thermometer (Comark, DT 300, Beaverton, OR, USA). Meat pH values were also recorded when opening the vacuum bags at each storage time (1, 2 and 3 weeks post slaughter).

Triplicate colour measurements were made on each freshly cut steak 2 h after opening the vacuum bag, then twice daily using a Minolta Chroma meter (CR-300, Japan) as found appropriate for red deer (*Cervus elaphus*) venison (Stevenson *et al.*, 1989). Days of acceptable colour (display life) were calculated as the time taken to reach a Minolta a^* value of 12 using linear interpolation between consecutive samples, as has been used previously for red deer venison (Stevenson *et al.*, 1989; Wiklund *et al.,* 2001b).

Drip loss (purge) was measured by the following procedure: (1) the combined weight of muscle and the vacuum pack was recorded before opening; (2) at opening, any surplus drip on the meat was removed using a paper towel and the drip-free weight of the meat recorded (Wiklund *et al.*, 2001b). The combined dry bag (average weight of 25 empty vacuum bags) and drip-free meat weights were subtracted from the unopened package weight to derive the total drip weight. Drip weight was then expressed as a percentage of the original weight of meat packed.

Sensory evaluation

The sensory evaluation was performed at the School of Hospitality, Culinary Arts and Meal Science (Grythyttan Campus, Örebro University, Sweden). A descriptive test, conventional profiling (ISO 6564, 1985), was carried out by a selected and trained sensory panel (ISO 8586-1, 1993) consisting of ten members. The sensory training was performed in accordance with ISO 6564 (1985). All assessments were carried out in a sensory laboratory with separate booths under normal white light (ISO 8589, 1988).

Upon thawing, the loin samples were put in a refrigerator at + 3 ºC for 17 h. The meat was cooked in a conventional oven at 150 °C to a core temperature of 68°C. Internal temperature in each loin was monitored with thermocouples (Type K, Pentronic AB, Gunnebo, Sweden) connected to a digital thermometer (Therma 1, Pentronic AB, Gunnebo, Sweden). At every session, the panel members were served six or seven meat samples at the same time, each sample consisting of two slices of meat. Samples were placed in Petri-dishes, coded with three-digit numbers and were served to the panel members in randomised order, at room temperature and in two replicates. The following attributes were selected and unanimously agreed upon during panel training; tenderness, juiciness, gamey flavour, liver flavour, bitter flavour, sweet flavour and off-flavour. An unstructured continuous line scale from 0 (low intensity) to 10 (high intensity) was used.

Statistical analysis

The experiment had a completely randomized design. Carcass, meat quality and sensory data were analysed by analysis of variance (ANOVA) fitting treatment group. All analyses were carried out in Genstat (Payne *et al.*, 2009).

Results and discussion

Carcass characteristics, meat pH and water-holding capacity

All results (carcass quality, meat quality data and sensory evaluation) from one animal in the

group fed linseed pellets (LPD) were excluded from the present study. This animal had an ultimate pH value in the loin muscle (LD) of 6.2 which is defined as DFD (Dark, Firm, Dry) meat, a persistent quality defect found in all meat species. A pH value of 5.5 – 5.7 is within the normal range, while values over 5.8 result in reduced shelf life, especially for vacuum packaged meat (Gill & Newton, 1981). Since a high pH value will affect shelf life (through microbiological spoilage), tenderness, colour and water-holding properties, it would influence the results of the study when the two reindeer pellet formulations were compared. All other measured meat pH values in the present study were below 5.8.

No significant differences were found when comparing the weights, conformation or trim fat of the carcasses from the two treatment groups (Table 2). The nutritional composition of the two feeds was very similar (Table 1) and the reindeer in the two treatment groups consumed equal amounts of feed according to reports from the reindeer herder responsible for feeding the animals every day. This is regarded as reasonable evidence that the palatability of the diet was not negatively affected by adding linseed cake to the feed formulation. Nutritional requirements of reindeer vary seasonally (Suttie & Webster, 1995), and other studies report that the composition of their natural summer diet is much higher in protein and mineral content to support growth (muscle, antler and hair) and lactation (Klein, 1970; Ryg & Jacobsen, 1982; White, 1992), compared with their winter diet. In Alaska, studies on different feed formulations for reindeer have been carried out in intensive production systems to try and maximize animal growth and performance based on feed ingredients grown in Alaska. Barley (*Hordeum vulgare*) and brome grass (*Bromus inermis*) have been used in feed mixtures together with protein supplements like fish or soy bean meal to increase production outcomes (Finstad *et al.*,

Table 2. Carcass and meat quality characteristics (means values with standard errors of the difference, SED) in *M. longissimus* (LD) from reindeer calves fed two commercial feed mixtures; conventional pellets (CPD; *n*=10) or linseed pellets (LPD; *n*=9)

Trait	Conventional pellets	Linseed pellets	SED	*P*- value
Carcass weight, (kg)	25.4	27.8	1.25	0.07
EUROP carcass conformation[1]	5.70	5.56	0.22	0.53
Trim fat[2]	4.70	4.78	0.21	0.71
Meat pH (LD)				
Storage time				
1 day	5.51	5.53	0.02	0.47
1 week	5.51	5.52	0.01	0.58
2 weeks	5.62	5.59	0.02	0.08
3 weeks	5.59	5.56	0.01	0.06
Drip loss (purge), %				
Storage time				
1 week	2.16	2.47	0.60	0.61
2 weeks	4.98	5.80	0.65	0.23
3 weeks	5.31	5.05	0.45	0.57

[1] The EUROP system used for carcass conformation in Sweden converted to figures:

E+	E	E-	U+	U	U-	R+	R	R-	O+	O	O-	P+	P	P-
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

[2] The EUROP trim fat classes used in Sweden converted to figures:

5+	5	5-	4+	4	4-	3+	3	3-	2+	2	2-	1+	1	1-
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

2004). The nutritional composition of the Alaskan standard reindeer feed mixtures had higher crude protein content (15 % vs. 10 %), higher energy content (13 MJ/kg vs. 10 MJ/kg) and lower fat content (2 % vs. 3 %) compared with the two pellet diets used in the present study. However, the Swedish reindeer pellets are designed to support maintenance and not to maximize growth/meat production since reindeer husbandry in Sweden is based on the sustainable use of natural pasture resources with the reindeer grazing in a free-range system. If feeding of reindeer is necessary - *i.e.* to prevent starvation or to reduce radioactive contamination in the meat - it is carried out during the time of the year when the seasonal growth is at its minimum (in winter) and therefore protein and energy content in the commercial reindeer pellets is adapted to suit this requirement.

Meat pH values did not differ between the treatment groups in the present study (Table 2). The phenomenon of increased meat pH values during chilled storage has previously been reported for red deer venison (Wiklund *et al.*, 2001b; 2010b) but was not found in the present study. The measured pH values varied between 5.46 and 5.65 which are values in the optimal range to safeguard meat quality and shelf life (Wiklund, 1996).

The present purge values at all storage times (1, 2 and 3 weeks at + 4 °C) agree well with the only other published data for fresh, chilled reindeer meat (Wiklund *et al.*, 2008; Table 2). A direct comparison of the data is possible since storage times and temperatures were similar in the present and previous studies. However, it should be noted that a comparison of the present purge values could only be applied to values collected from non-electrically stimulated reindeer carcasses in the Alaskan study (Wiklund *et al.*, 2008). All reindeer carcasses in Sweden are processed without electrical stimulation. In the literature, purge values for deer meat have been reported. After 3 weeks of chilled storage purge values ranging between 0.6 and 3.7% in red deer samples (LD) (Wiklund *et al.*, 2001b; 2006) and values between 2.0 and 3.6% for fallow deer (*Dama dama*) LD were reported (Wiklund *et al.*, 2005). The purge values from these previous deer studies were lower than those of the present study and the earlier reindeer study from Alaska (Wiklund *et al.*, 2008). It should be noted that the red deer studies (Wiklund *et al.*, 2001b; 2006) were performed within the practices of the New Zealand venison industry where fresh meat is stored and transported at –1.5 °C while in the fallow deer study (Wiklund *et al.*, 2005), the earlier reindeer study (Wiklund *et al.*, 2008) and in the present study samples were stored at +2 - 4 °C.

The seasonal growth pattern for deer has been related to muscle protein turnover and proteolytic enzyme activity and it has been suggested that seasonal variation in protein accretion and catabolism could be related to proteolytic enzyme activity and possibly meat tenderness (Wiklund *et al.*, 2010b). This would likely impact on other meat quality attributes such as water-holding capacity (purge) also. Venison is usually more tender than beef, and, for some deer species like reindeer and fallow deer, ageing of the meat beyond 1-3 days post slaughter is not necessary at all (Barnier *et al.*, 1999; Sims *et al.*, 2004). The phenomenon of fast tenderisation in venison has been explained by high activity of proteolytic enzymes (calpains and cathepsins) (Wiklund *et al.*, 1997; Farouk *et al.*, 2007). A recent study from New Zealand found that the most tender red deer samples (LD) had the highest drip loss and purge values at 1 day post slaughter as well as during the extended storage period (up to 14 weeks at – 1.5 °C) (Wiklund *et al.*, 2010b). The high purge values found in the present study (Table 2) and in the previous study of reindeer (Wiklund *et al.*, 2008) could also be a reliable indication of increased tenderness in reindeer meat.

Colour

The results from the present study demonstrated no significant difference in colour display life (hours of Minolta a^* value ≥ 12) in the LD samples at any of the storage times (1 day, 1, 2 and 3 weeks at +4 °C) from the two treatment groups (CPD and LPD; Fig. 1). The decrease in a^* value during display at all the mentioned storage times is shown in Fig. 2.

Oxidation of deoxymyoglobin and oxymyoglobin to metmyoglobin accounts for the discoloration (from a bright red to a brownish red colour) of meat in retail display conditions (Liu *et al.*, 1996). Red deer venison on display had poor colour stability compared with beef, and it was suggested that the deer meat is prone to oxidative deterioration possibly due to high levels of pro-oxidants like iron (Fe) and copper (Cu) (Drew & Seman, 1987; Stevenson-Barry *et al.*, 1999). Colour display life of fresh, chilled reindeer meat has not been reported in the literature. However, comparing the present results with the previous studies on fallow deer (Wiklund *et al.*, 2005) and red deer (Wiklund *et al.*, 2006), also referred to above in the comparison of purge values, the display life of reindeer meat (LD) after 1 week of storage at +4 °C was 78 hours (approximately 3 days). After the same storage time, values for fallow

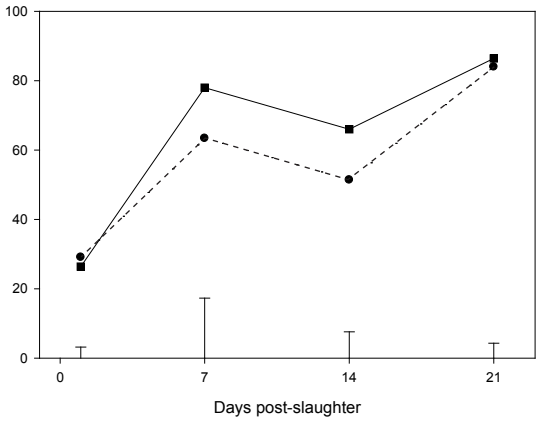

Fig. 1. Mean display life (hours of Minolta a* value ≥ 12) in *M. longissimus* from reindeer from two feeding treatments (■ conventional pellets (CPD), *n*=10 and ● linseed pellets (LPD), *n*=9), measured at one day post slaughter, and after 1, 2 and 3 weeks of refrigerated storage (+ 4 °C), with error bars indicating standard error of difference (SED).

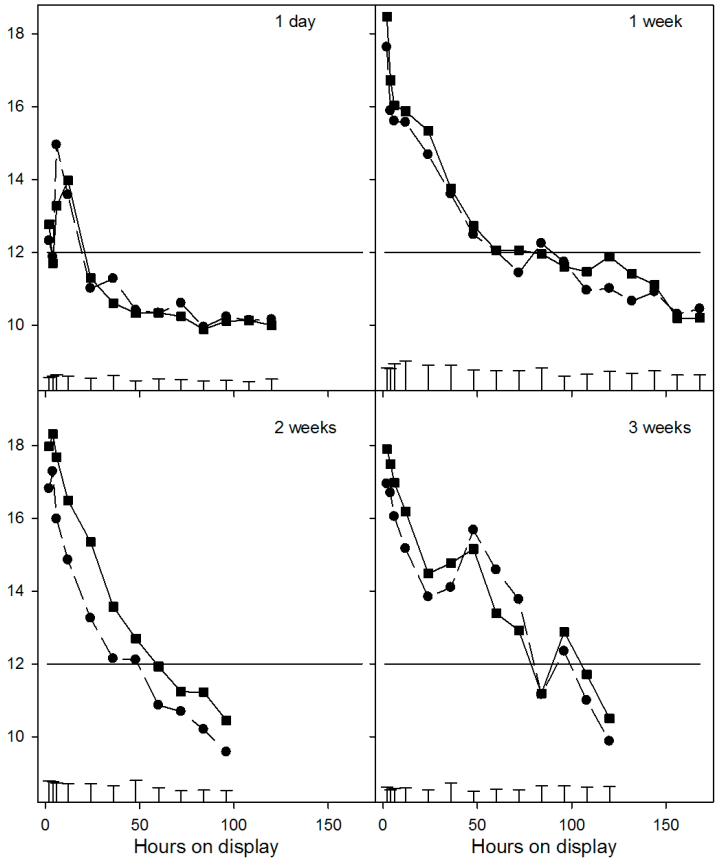

Fig. 2. Mean Minolta a* values in *M. longissimus* from reindeer from two feeding treatments (■ conventional pellets (CPD), *n*=10 and ● linseed pellets (LPD), *n*=9), measured at one day post slaughter and after 1, 2 and 3 weeks (0-200 h of display) of refrigerated storage (+ 4 °C), with error bars indicating standard error of difference (SED).

deer LD were around 200 hours (approximately 8 days) and for red deer LD around 90 hours (approximately 4 days). As previously described the storage temperatures were similar in the present study and the fallow deer study (+2 to +4°C) while the red deer samples were stored at -1.5 °C. The reason for the obvious difference in colour display life of the meat from the different deer species is unknown.

Sensory evaluation

No significant differences in any of the sensory attributes were demonstrated in the present study when comparing the LD samples from reindeer fed conventional reindeer pellets (CPD) or linseed pellets (LPD). However, the samples from LPD fed reindeer showed a tendency to be more tender (sensory score of 6.4 vs. 5.2; P= 0.06) and juicy (5.8 vs. 5.0; P=0.07) than the meat samples from CPD fed reindeer. Sensory scores for tenderness and juiciness in reindeer meat (LD) have been reported to be intermediate to high (Wiklund *et al.*, 2003; Renecker *et al.*, 2005; Rincker *et al.*, 2006), and the results from the present study are in good agreement with these previous studies. Flavour differences in reindeer meat has been related to diet prior to slaughter, so that grazing free-ranging animals produced meat with more "wild" and "gamey" flavour compared with reindeer fed grain-based feed mixtures (Wiklund *et al.*, 2003; Finstad *et al.*, 2007). It has been suggested that natural grazing is an important contributor to the development of various "wild" flavours in meat, possibly depending partly on effects of the fatty acid (FA) composition (Wiklund *et al.*, 2003). The present study demonstrated no flavour differences between the two treatment groups, however slightly higher values for the attribute gamey flavour (a mean value of 3.6 over the two treatment groups) compared with the attributes liver flavour (mean value of 1.7), bitter flavour (mean value of 1.3) and sweet flavour (mean value of 1.3) were reported. Very few remarks on off-flavour were reported in the present study and they were described as "blood", "iron" and "lamb/sheep". Earlier published data using the same animal material as in the present study demonstrated that the LPD pellets enriched with linseed positively affected the fatty acid composition and decreased the ratio of n-6/n-3 (omega-6/omega-3) FA in reindeer meat (LD) compared with CPD fed reindeer (Sampels *et al.*, 2006). When the FA composition of reindeer meat from animals grazing natural pasture was compared with that of LPD fed reindeer the total content of omega-3 fatty acids were the same, however the amount of the long chained omega-3 FA 22:5 and 22:6 were higher in the reindeer grazing natural pasture (Sampels *et al.*, 2006). FA composition of the CPD and LPD pellets and samples of reindeer winter pasture (lichens; *Cladina arbuscula, Cetraria islandica, Cladina stellaris* and *Cladina mitis*) was analyzed and the long chained omega-3 FA 22:5 and 22:6 were found only in the natural pasture (Sampels *et al.*, 2006). The authors suggested that these results indicated that reindeer are not able to use the omega-3 FA 18:3 provided through the linseed for synthesis of omega-3 FA such as 22:5 and 22:6 and that these long chained FA need to be ingested via the diet (Sampels *et al.*, 2006), *i.e.* in this case the natural pasture. It is therefore hypothesized that the unique flavour of reindeer meat, sometimes described as "wild" or "gamey", could be an effect of flavour compounds directly associated with long chained omega-3 fatty acids such as 22:5 and 22:6 and therefore completely dependent on the reindeer grazing their natural pasture. This hypothesis would explain the lack of significant differences in meat flavour attributes between CPD and LPD fed reindeer and the low over all sensory scores for the attribute "gamey flavour" in the present study.

Conclusions

The reindeer pellets containing linseed cake (LPD) were palatable for the animals and produced carcasses and meat of similar quality to that of reindeer fed conventional reindeer pellets (CPD). A tendency towards more tender and juicy meat from LPD fed reindeer was observed in the sensory evaluation. The present results together with information already published from the same study support the proposition that reindeer meat has a unique flavour, although not pronounced in any sample in the present study, to be an effect of flavour compounds directly associated with long chained omega-3 fatty acids such as 22:5 and 22:6 and therefore completely dependent on the reindeer grazing their natural pasture.

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References

Åhman, B. 1996. Effect of bentonite and ammonium-ferric(III)-hexacyanoferrate(II) on uptake and elimination of radiocaesium in reindeer. – *Journal of Environmental Radioactivity* 31:29-50.

Åhman, B. 1999. Transfer of radiocaesium via reindeer meat to man – effects of countermeasures applied in Sweden following the Chernobyl accident. – *Journal of Environmental Radioactivity* 46 (1):113-120.

Åhman, B. & Danell, Ö. 2001. Reindeer feeding - possibilities, effects and economy. – *In*: Haugerud, R.E. (ed.). *Programme and Abstracts, 11th Nordic Conference on Reindeer Research,* Kaamanen, Finland. – *Rangifer* Report No. 5:14.

Barnier, V. M. H., Wiklund, E., van Dijk, A., Smulders, F. J. M., & Malmfors, G. 1999. Proteolytic enzyme and inhibitor levels in reindeer (*Rangifer tarandus tarandus* L) vs. bovine longissimus muscle, as they relate to ageing rate and response. – *Rangifer* 19:13-18.

Drew, K. R. & Seman, D. L. 1987. The nutrient content of venison. – *In: Proceeding of Nutritional Society NZ* 12:49-55.

Gill, C. O. & Newton, K. G. 1981. Microbiology of DFD beef. – *In:* Hood, D. E. and Tarrant, P. V. (eds.). *The problem of Dark-Cutting in beef*. Martinus Nijhoff, Den Haag, pp. 305-327.

Farouk, M. M., Beggan, M., Hurst, S., Stuart, A., Dobbie, P., & Bekhit, A. E. D. 2007. Meat quality attributes of chilled venison and beef. – *Journal of Food Quality* 30:1023-1039.

Finstad, G., Wiklund, E., Long, K., Rincker, P. J., Oliveira, A. C. M., & Bechtel, P. J. 2007. Feeding soy or fish meal to Alaskan reindeer (*Rangifer tarandus tarandus*) – effects on animal performance and meat quality. – *Rangifer* 27:59-75.

Helle, T. 1984. Foraging behaviour of the semi-domestic reindeer (*Rangifer tarandus* L.) in relation to snow in Finnish Lapland. – *Report from Kevo Subarctic Research Station* 19:35-47.

Hoffman, L. C. & Wiklund, E. 2006. Game and venison – meat for the modern consumer. – *Meat Science* 74:197-208.

ISO 6564. International Organisation for Standardization. 1985. *Sensory analysis - methodology - flavour profile methods*. ISO 6564:1985 (E), Geneve, Switzerland.

ISO 8586-1. International Organisation for Standardization. 1993. *Sensory analysis - general guidance for the selection, training and monitoring of assessors – Part 1: Selected assessors*. ISO 8586-1:1993 (E), Geveve, Switzerland.

ISO 8589. International Organisation for Standardization. 1988. *Sensory analysis - general guidance for the design of test rooms.* ISO 8589:1988 (E), Geveve, Switzerland.

Klein, D. R. 1970. Nutritive quality of Alaskan range forage and associated growth and welfare of reindeer and caribou. *Completion report to the U. S. Department of the Interior*, Bureau of Land Management. 30pp.

Lantmännen. 2011. Product specification (in Swedish) for conventional reindeer pellets. Available at: http://www.lantmannenlantbruk.se/

Liu, Q., Scheller, K. K., Arp, S. C., Schaefer, D. M., & Williams, S. N. 1996. Titration of fresh meat colour stability and malondialdehyde development with Holstein steers fed vitamin E-supplemented diets. – *Journal of Animal Science* 74:117-126.

Payne, R. W., Harding, S. A., Murray, D. A., Soutar, D. M., Baird, D. B., Welham, S. J., Kane, A.F., Gilmour, A.R., Thompson, R., Webster, R., Tunnicliffe, & Wilson, G. 2009. *GenStat Release 12 Reference Manual*, Hemel Hempstead: VSN International.

Renecker, T. A., Renecker, L. A., & Mallory, F. F. 2005. Relationships between carcass charactieristics, meat

quality, age and sex of free-ranging Alaskan reindeer: a pilot study. – *Rangifer* 25:107-121.

Rincker, P. J., Bechtel, P. J., Finstad, G., van Buuren, R. G. C., Killefer, J., & McKeith, F. K. 2006. Similarities and differences in composition and selected sensory attributes of reindeer, caribou and beef. – *Journal of Muscle Foods* 17:65-78.

Ryg, M. & Jacobsen, E. 1982. Seasonal changes in growth rate, feed intake, growth hormone, and thyroid hormones in young male reindeer (*Rangifer tarandus tarandus*). – *Canadian Journal of Zoology* 60:15-23.

Sami Parliament. 2009. Föreskrifter om ändring i Sametingets föreskrifter (STFS 2007:5) om ersättning till renskötselföretag för vissa merkostnader och förluster med anledning av Tjernobylolyckan. Kiruna, Sweden (in Swedish).

Sampels, S. 2005. Fatty acids and antioxidants in reindeer and red deer – Emphasis on animal nutrition and consequent meat quality. Doctoral thesis. – *Acta Universitatis Agriculturae Sueciae* 2005:31. Department of Food Science, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Sampels, S., Pickova, J., & Wiklund, E. 2005. Influence of production system, age and sex on carcass parameters and some biochemical characteristics of reindeer (*Rangifer tarandus tarandus* L) meat. – *Rangifer* 25:85-96.

Sampels, S., Wiklund, E., & Pickova, J. 2006. Influence of diet on fatty acids and tocopherols in *M. longissimus dorsi* from reindeer. – *Lipids* 41:463-472.

Sims, K. L., Mulley, R. C., Hutchison, C. L., & Wiklund, E. 2004. Post slaughter management of fallow deer (*Dama dama*). Effect of pelvic suspension method on meat tenderness. – *In: Proceedings 7th Biennial Deer Industry Conference*, Mt Gambier, Australia.

Stevenson-Barry, J., Duncan, S., & Littlejohn, R. 1999. Venison vitamin E levels and the relationship between vitamin E, iron and copper and display life for venison and beef. – *In: Proceedings 45th International Congress of Meat Science and Technology*, Yokohama, Japan, pp. 458-459.

Stevenson-Barry, J. M., Seman, D. L., Weatherall, I. L., & Littlejohn, R. P. 1989. Evaluation of venison colour by an objective method using CIELAB values. – *Journal of Food Science* 54:1661–1662.

Suttie, J. M. & Webster, J. R. 1995. Extreme seasonal growth in Arctic deer: comparisons and control mechanisms. – *American Zoology* 35:215-221.

Swedish Board of Agriculture. 2002. Föreskrifter om ändring i Statens jordbruksverks föreskrifter (SJVFS 1998:127) om klassificering av slaktkroppar. Jönköping, Sweden (in Swedish).

White, R. G. 1992. Nutrition in relation to season, lactation, and growth of north temperate deer. – *In:* R. D. Brown (ed.). *The Biology of Deer.* Springer-Verlag, New York, USA, pp 407-417.

Wiklund, E. 1996. Pre-slaughter handling of reindeer (*Rangifer tarandus tarandus* L) - effects on meat quality. Doctoral thesis; *Acta Universitatis Agriculturae Sueciae*, 1996:11. Department of Food Science, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Wiklund, E., Barnier, V. M. H., Smulders, F. J. M., Lundström, K., & Malmfors, G. 1997. Proteolysis and tenderisation in reindeer (*Rangifer tarandus tarandus L*) bull longissimus thoracis muscle of various ultimate pH. – *Meat Science* 46: 33-43.

Wiklund, E., Dobbie, P., Stuart, A., & Littlejohn, R. P. 2010b. Seasonal variation in red deer (*Cervus elaphus*) venison drip loss, calpain activity, colour and tenderness. – *Meat Science* 86:720-727.

Wiklund, E., Finstad, G., Johansson, L., Aguiar, G., & Bechtel, P. J. 2008. Carcass composition and yield of Alaskan reindeer (*Rangifer tarandus tarandus*) steers and effects of electrical stimulation applied during field slaughter on meat quality. – *Meat Science* 78:185-193.

Wiklund, E., Johansson, L., & Malmfors, G. 2003. Sensory meat quality, ultimate pH values, blood parameters and carcass characteristics in reindeer (*Rangifer tarandus tarandus* L) grazed on natural pastures or fed a commercial feed mixture. – *Food Quality and Preference* 14:573-581.

Wiklund, E., Hutchison, C., Flesch, J., Mulley. R., & Littlejohn, R. P. 2005. Colour stability and waterholding capacity of *M. longissimus* and carcass characteristics in fallow deer (*Dama dama*) grazed on natural pasture or fed barley. – *Rangifer* 25:97-105.

Wiklund, E., Pickova, J., Sampels, S., & Lundström, K. 2001a. Fatty acid composition in *M. longissimus lumborum*, ultimate muscle pH values and carcass parameters in reindeer (*Rangifer tarandus tarandus* L) grazed on natural pasture or fed a commercial feed mixture. – *Meat Science* 58:293-298.

Wiklund, E., Sampels, S., Manley, T. R., Pickova, J., & Littlejohn, R. P. 2006. Effects of feeding regimen and chilled storage on water holding capacity, colour stability, pigment content and oxidation in red deer (*Cervus elaphus*) meat. – *Journal of the Science of Food and Agriculture* 86:98-106.

Wiklund, E., Sikku, O-J. & Blom, A. 2010a. Renlycka – a Sami quality trade mark for reindeer meat. – *In*: Haugerud, R. E., Hatteng, B., & Nystad Eskonsipo, B. M. (eds.). 16th Nordic Conference on Reindeer and Reindeer Husbandry Research, Tromsø, 2010. – *Rangifer* Report 14:113-114.

Wiklund, E. & Smulders, F. J. M. 2011. Muscle biological and biochemical ramifications of farmed game husbandry with focus on deer and reindeer. - *In:* Paulsen, P., Bauer, A.,Vodansky, M., Winkelmayer, R., & Smulders, F. J. M. (eds.). *Game meat hygiene in focus. Microbiology, epidemiology, risk analysis and quality.* Wageningen Academic Publishers, The Netherlands, pp. 297-311.

Wiklund, E., Stevenson-Barry, J. M., Duncan, S. J., & Littlejohn, R. P. 2001b. Electrical stimulation of red deer (*Cervus elaphus*) carcasses – effects on rate of pH-decline, meat tenderness, colour stability and water holding capacity. – *Meat Science* 59:211-220.

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Vattenhållande förmåga, färgstabilitet och sensoriska egenskaper i kött (*M. longissimus dorsi*) från renar som utfodrats med två typer av kommersiellt foder

Abstract in Swedish / Sammanfattning: Tjugo renkalvar (ålder 10 månader) ingick i undersökningen. De utfodrades två typer av pelleterat renfoder *ad libitum* i två månader innan slakt. Tio renkalvar fick konventionellt renfoder (CPD; Renfor Bas, Lantmännen, Holmsund, Sverige; kontrollfoder) och tio kalvar fick pellets med tillsatt linfrökaka (LPD; försöksfoder). Renarna slaktades enligt standardmetoder vid Arvidsjaur Renslakt AB i Arvidsjaur, Sverige. En dag *post mortem* styckades båda ytterfiléerna (*M. longissimus dorsi*; LD) ut från slaktkropparna, vänster LD användes för sensorisk analys och höger LD för mätningar av färgstabilitet och vattenhållande förmåga. Höger LD delades i fyra bitar som slumpmässigt fördelades på fyra lagringstider; 1 dag, 1, 2 och 3 veckors lagring vid +4 °C och vakuumförpackades. Färgstabiliteten mättes efter alla fyra lagringstiderna medan den vattenhållande förmågan registrerades efter 1, 2 och 3 veckors lagring vid +4 °C. Vänster LD vakuumförpackades, frystes och förvarades vid -20 °C till sensorisk analys utfördes. Inga signifikanta skillnader kunde påvisas i slaktkroppskvalitet, färgstabilitet eller vattenhållande förmåga när de två grupperna LPD och CPD jämfördes. Däremot fanns en tendes att köttet från LPD-fodrade renar var mörare (P= 0.06) och saftigare (P=0.07) jämfört med kött från CPD-gruppen. Inga smakskillnader i köttet från de två utfodringsgrupperna rapporterades. Den unika renköttssmaken föreslås vara en effekt av smakkomponenter direkt kopplade till de långa fleromättade (omega-3) fettsyrorna som exempelvis 22:5 och 22:6, som tidigare visats finnas i betesväxter men inte i kommersiellt renfoder, och därför helt beroende av att renarna betar sitt naturliga bete.