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Composition and some quality characteristics of the longissimus muscle of reindeer in Norway compared to farmed New Zealand red deer

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ABSTRACT

Norwegian reindeer of Finnmark county live under harsh conditions on extensive feed sources. Thus the meat may have special qualities. *M. longissimus lumborum* from 30 animals was investigated with respect to carcass and meat quality and compositional/nutritional characteristics. Meat from calves had a higher myofibrillar fragmentation index and tenderness, and had lighter, redder and more yellow colour than meat from adult reindeer. Regarding nutritional compounds the meat from calves had lower antioxidant capacity, and higher taurine levels than adults, while the levels of iron, carnosine, anserine, and vitamin E were similar. Carcass weights of the adult reindeer were lower than the weights reported for Swedish reindeer and New Zealand farmed red deer. Reindeer muscles had higher antioxidant capacity, shorter sarcomeres, smaller muscle fibre diameters, higher n−6/n−3 ratios of fatty acids in the intramuscular fat and higher muscle taurine levels relative to values for the same muscle of New Zealand farmed red deer.

1. Introduction

There are about 150000 reindeer grazing on 45% of the land of Norway, these animals belong to 550 reindeer (*Rangifer tarandus*) herding units and around 60000 animals are slaughtered per year. Norwegian reindeer from the Northern part of Norway (Finnmark county) are extensively raised and supplementary feeding is only done in some cases to improve their nutritional status. Recent research on reindeer in Scandinavia (Sweden) has focussed on the possibility of manipulating the fatty acid composition in reindeer meat (Sampels, Pickova, & Wiklund, 2004; Sampels, Pickova, & Wiklund, 2005; Sampels, Turner, Öström, & Pickova, 2010; Sampels, Wiklund, & Pickova, 2006, and Wiklund, Pickova, Sampels, & Lundstrom, 2001). Pasture fed adult Swedish reindeer with an average carcass weight of 31.5 kg had a n−6/n−3 ratio of 2 when the intramuscular fat content was 2.5% in *M. longissimus lumborum* (Wiklund et al., 2001). Sampels et al. (2005) reported that for adult males and females with carcass weights above 30 kg and grazing calves with carcass weights around 21 kg, the intramuscular fat levels for adults were between 2.6 and 4.2% (2–3 year-old animals) and for calves (10 months old) just above 2%. Intensive feeding can increase carcass weights and intramuscular fat levels (Sampels et al., 2005; Wiklund et al., 2001). Wiklund et al. (2001) reported an average carcass weight of 44.2 kg for Swedish reindeer males (6–24 months) fed with commercial reindeer pellets based on oat, wheat, bran products, sugar beet pulp and soy bean meal. These males had a n−6/n−3 ratio of 8.1, but they were heavier with more than 6% of the carcass weight as fat. Using linseed-algae (Sampels et al., 2010) in the diet of reindeer in intensive systems seems attractive since both heavier animals and a n−6/n−3 ratio of about 4 can be achieved.

Publications regarding the meat quality of Norwegian reindeer from the northernmost county (Kautokeino region in Finnmark, latitude ~70°) are scarce and unfortunately basically related to the Chernobyl accident in 1986 (e.g. Tveten, Brynildsen, Amundsen, & Bergan, 1998). This accident also induced low profitability in reindeer meat production and recovery has taken time. Nevertheless, some research has investigated the effects of stress during transport to the slaughterhouse plus unwanted flavour of the meat (Hanssen, Kyrkjebo, Opstad, & Prosch, 1984; Hanssen & Skei, 1990; Rogstadkjærnet & Hanssen, 1985; Skjenneberg, Jacobsen, & Movinkel, 1974). Other studies have suggested the possibility that reindeer meat may actually be a healthy food commodity and even reduce the risk of cancer (Brox et al., 2002; Brustad, Parr, Melhus, & Lund,

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2008; Nilsen, Utsi, & Bonaa, 1999; Offergaard, 1959; Ringstad, Aaseth, Johnsen, Utsi, & Thomasen, 1991). Traditional meat quality aspects concerning palatability and appearance have not been investigated.

The current study had the primary objective of evaluating the effects of gender and age at slaughter on quality characteristics of meat from *M. longissimus lumborum* of reindeer processed in a commercial slaughter house in Kautokeino, Norway. The variables studied included meat colour, drip loss, tenderness, and selected characteristics of muscle that play, or can play, a role in determining tenderness. In addition, compounds that may be positive from a health perspective (carnosine, taurine, iron, α-tocopherol) were included. Carnosine and taurine are regarded as antioxidants, but may be multifunctional in activity. Norwegian reindeer meat is appreciated by Norwegian consumers, but nevertheless there is, at least in certain regions of Norway, easy access to farmed red deer meat produced in New Zealand. Therefore, a second objective was to make comparisons between meat from Norwegian reindeer from Finnmark and New Zealand farmed red deer (*Cervus elaphus*).To the extent possible, the analytical methods used were kept close to those used in a similar study in New Zealand with venison from the same muscle of farmed red deer (Purchas, Triumf, & Egelandsdal, 2010).

2. Materials and methods

2.1. Animals and sample collection

Samples of *M. longissimus lumborum* were collected at the reindeer slaughter plant (Mt Slakt A/S) in Kautokeino, Norway from 10 reindeer hinds (>1.5 years) and 10 reindeer stags (>1.5 years). These animals had grazed on summer pasture on an island off the coast of Finnmark. In addition, *M. longissimus lumborum* samples were taken from 5 female and 5 male calves (about 6 months old) from a region where the reindeer had grazed on summer pasture. The chill after slaughter started at 6–8 °C with a reduction to a deep leg temperature of <2 °C overnight, approximately 9–15 h after dressing of the carcass. The carcasses were selected to be representative of those being processed at the slaughterhouse at that time (in January, during the winter season). After deboning the following day, loins were vacuum-packed, and stored at 2–3 °C for 7 days *post mortem* before being frozen at approximately −20 C°. Samples were thawed at 3–4 °C for approximately 15 h and used for all measurements except for pH that was measured on fresh muscle before freezing.

2.2. Meat quality assessments

Measurements were replicated. However, the number (2–12) of replicates varied with the analytical method.

2.2.1. pH

Ultimate meat pH was measured in a homogenate of 2–2.5 g of muscle in 10 mL of 150 mM KCl (Bendall, 1973).

2.2.2. Water-holding capacity (expressed juice)

Water holding capacity was assessed by the filter-press method with samples (500 ± 20 mg) and a pressure of 10 kg for 5 min. Expressed juice is given by the wetted area per unit weight of sample ($cm^2 \cdot g^{-1}$). The area was calculated from 8 diameters, assuming the wetted area was a circle (Hamm, 1986).

2.2.3. Drip loss (% weight loss)

A muscle sample (35 ± 5 g) was suspended in a plastic bag at 1–3 °C for 24 h and the liquid collected in the bag was weighed (Honikel, 1998).

2.2.4. Cooking loss

The difference in weight (after drying the surface with a paper towel) of the uncooked steak and steak heated for 90 min in a waterbath at 60 or 70 °C was expressed as a percentage of the uncooked weight (Purchas et al., 2010).

2.2.5. Sarcomere length

Images were taken on finely comminuted, fixed fibres/fibrils using a microscope (Leica DMRE, Wetzlar, Germany) equipped with the ImagePro software programme (Bethesda, USA). Calculations were made in Image J (http://rsb.info.nih.gov/ij/). The scale was acquired by imaging an object micrometrer with 2 μm scale division.

2.2.6. Myofibrillar fragmentation index

The filtration method used was that described by Purchas et al. (2010) using a stainless steel mesh with 231 μm gaps. Values could range from 100, when all fragments passed through the mesh to approximately 72, when none of the fragments passed through.

2.2.7. Warner–Bratzler shear force

A square blade attached to a TA-DDi Texture Analyser (Stable Micro Systems Ltd, Godalming, England) was used to shear cores that had a cross-section across the fibres of 13 × 13 mm. Six cores and 2 shear values per core were obtained per animal per cooking temperature from 25 mm-thick steaks that had been heated as for cooking loss. Immediately after cooking, the fluid from the bag was poured off, and the meat was chilled overnight at 1–3 °C. From the force deformation curve, peak force and 'work index' (here 'work done', Purchas & Aungsupakorn, 1993) were calculated using the instrument's software (Texture Expert for windows v2.61).

2.2.8. Colour

Frozen-thawed and then chill-stored (+4 °C) samples over-wrapped with polyethylene film and exposed to air for 30 min, 2.5 h, 16 h and 7 days were measured twice; (i) L*, a* and b* values were obtained using a Minolta Chromameter (CR-400/410) with 10° angle of view and illuminate C, and (ii) the reflectance spectra (400–1100 nm) were obtained using an XDS Near infrared Instrument (Foss NIR Systems Inc., USA). Only reflectance values at 580 nm and 630 nm were used. The proportion of oxyglobin to metmyoglobin was estimated using the ratio R630/R580 assumed to vary between 1 and 5 (Hunt et al., 1991).

2.3. Analytical measurements

2.3.1. Haem iron

0.5 g of comminuted meat was dissolved in 0.75 mL water, 5 mL acetone and 124 μL concentrated hydrochloric acid (HCl). The solution was centrifuged at 3000 g for 20 min, and the absorbance of the supernatant was measured (Shimadzu, UV1610) at 640 nm after being filtered through glass filter paper (Whatman GFA, hardened 54, 12.5 cm) (Carpenter & Clark, 1995; Hornsey, 1956). All assays were performed in duplicate.

2.3.2. Non-haem iron

The method was based on the Ferrozine method described by Ahn, Wolfe, and Sim (1993) and Carter (1971). 1 gramme fresh sample was dissolved in 2.5 mL of 0.1 M citrate phosphate buffer (pH 5.5). Following addition of 1 mL of 2% ascorbic acid in 0.2 M HCl, it was left at room temperature for 15 min. Then 2 mL of 11.3% tri-chloro acetic acid was added and the resulting mixture was centrifuged at 3000 g for 10 min. To 2 ml of supernatant, 0.8 mL of 10% ammonium acetate and 0.2 ml ferrozine reagent were added and the absorbance measured at 562 nm against a standard curve. Standard $FeCl_3$ solutions were bought as Titrisol from Merck.

2.3.3. Taurine, anserine and carnosine

These were extracted by homogenising approximately 1 g of fresh reindeer meat with 9 mL distilled water and 1 mL of 20 mM norleucine, which served as an internal standard. The sample was

homogenised at 20,000 rpm using an Ultra Turrax T25 basic (IKA Werke GmbH, Staufen, Germany) for 15 s. 1 mL of 35% sulfosalicylic acid was added for removal of proteins followed by another 15 h of homogenization. After centrifugation at 20,000 *g* and 4 °C for 10 min the supernatant was diluted 1:5 with a lithium citrate buffer, pH 2.2. Samples were analysed by chromatographic separation on an ion exchange column, followed by post-column derivatisation with ninhydrin and ultra violet detection at 570 nm. The analysis was performed using a Biochrom 30 amino acid analyzer (Biochrom Co, Cambridge, UK) and the UV signals were analysed by Chromeleon software (Dionex, Sunnyvale, CA, USA) and compared to A9906 physiological amino acids (Sigma Chemicals Co, St. Louis, MO, USA), according to Mierke-Klemeyer et al.(2008).

2.3.4. Vitamin E

Cold extraction (30 min, in the dark) of 2 g reindeer meat, cut in small pieces, was carried out in iced water/2-propanol (2/16) containing 20 mg/L butylated hydroxy toluene. Following extraction, 3 mL were centrifuged at 2160 *g* for 15 min (approx. 10 °C). The supernatants were collected and analysed with a LC 1100 system, equipped with a wellplate autosampler G1367A, binary pump G1316A, column thermostat G1312A, Fluorescence detector G1321A (Agilent Technologies, Palo Alto, CA). Separation was performed on a Zorbax SB-C18 column 4.6×50 mm pn 822975–902 (Agilent Technologies, Palo Alto, CA). The composition of the mobile phase was 98% methanol and 2% water, and elution was performed isocratically with a flow rate of 1.2 mL/min and a run time of 4 min. The injection volume was 25 μL, and the column temperature was at 60 °C. The fluorescence detector was at excitation 295 nm and emission 330 nm.

2.3.5. Lipid content

The lipid content of the reindeer meat was analysed by the Folch method (Folch, Lees, & Sloan-Stanley, 1957) with some modifications. Samples (15 g) were homogenised and then blended with 180 mL chloroform/methanol (2/1) and 33.4 mL 0.88% NaCl. The mixture separated into two phases. The lower phase was recovered and the solvent was evaporated before weighing the lipid.

2.3.6. Fatty acid composition

Extracted lipids were dissolved in 2 mL hexane; 1.5 mL sodium methanolate (3.33 mg Na/mL methanol) was added. The tubes were capped and stirred for 30 min to separate into two phases. The upper phase was analysed using gas chromatography. A 6890 N GC with a split/splitless injector, a 7683B automatic liquid sampler and flame ionisation detection (Agilent Technologies, Palo Alto, CA) were used. Separation was performed with a SP-2380 (60 m×0.25 mm i.d. ×0.20 μm film thickness) column (Supelco). The temperature programme was an initial 90 °C with a 1 min hold, ramp 70 °C/min to 150 °C, then 5 °C/min to 235 °C with a 5 min hold, then 120 °C/min to 245 °C with an 8 min hold. Injector temperature was 250 °C. Carrier gas was H_2 with a pressure of 13000 kPa. Fatty acid analysis was performed by autoinjection of 1 μL of each sample at a split ratio of 80/1, constant flow mode, velocity 20.4 cm/s. The flame ionisation detector temperature was 270 °C with H_2, air, and N_2 make-up gas flow rates of 40, 450, and 9 mL/min, respectively. The run time for a single sample was 32 min.

2.3.7. Antiradical power (ARP)

The antioxidant activity was determined by using 2,2-diphenyl-1-picrylhydrazyl (DPPH) as described by Brand-Williams, Cuvelier, and Berset (1994) with some modifications (Mielnik et al., 2007). Fresh DPPH (25 mg/L) in ethanol was prepared daily and muscle samples (2.5 g) were homogenised with 10 mL of absolute ethanol. The filtered supernatants were mixed with 3.2 mL DPPH solution and ethanol to get a total volume of 4 mL. The reduction of the DPPH free radical was measured by the absorbance at 515 nm after 120 min of incubation. Absorbance of a blank sample containing 0.8 mL absolute ethanol and 3.2 mL DPPH solution was taken as 100%. The percentage of remaining DPPH was calculated and plotted against the sample concentration to obtain the amount of sample required to decrease the initial DPPH concentration by 50% (EC50). Antioxidant capacity is given as the reciprocal of EC50, the antiradical power (ARP) in units of mg of DPPH per gramme meat.

2.4. Statistical analysis

2.4.1. Analysis for reindeer data

Data were analysed using the general linear model procedure (GLM) within the computer programme SAS (with Type 1 Sums of squares). Animal age (adult vs calf) and gender (male vs female) were the main effects in a factorial design. Tukey's multiple comparison test between groups was used to calculate significant differences when more than two groups were involved, such as for the several consecutive measurement of meat colour. The results are shown as means with an overall model residual standard deviation (RSD).

In analysing changes of colour over time a nested model was used so that gender and age were tested against animal within each gender-by-age group. Time and its interaction with age and gender were tested against the overall error. Means are shown as bar graphs with standard errors of the mean (SEM) bars.

2.4.2. Comparisons between reindeer and New Zealand red deer

The statistical model used for the two New Zealand deer groups and the four reindeer groups combined, was also a GLM analysis with the three groups of New Zealand red deer, adult reindeer, and reindeer calves. Gender groups were combined for this analysis.

3. Results and discussion

3.1. Carcass characteristics

Carcasses of adult animals were heavier (P = 0.002) than those of calves and those of females were larger (P = 0.025) than males for the adults (Table 1). Intramuscular fat was very low for all groups and particularly low for adult males (Table 1) but group differences were not significant. These results are consistent with earlier studies by Mielnik et al. (2007) on Norwegian reindeer meat in showing very low amounts of intramuscular fat (0.5–1.6%). However, Mielnik et al.

Table 1
Numbers of animals and means for carcass weight, intramuscular fat percentage, and steak weights for the two cooking temperatures for male and female reindeer within adult and calf groups.

	Adult		Calf		Effect (P value)		R^2 (%), RSD
	Male	Female	Male	Female	Age	Gender	
Number of animals	10	10	5	5			
Approximate age (yr)	>1.5	>1.5	0.5	0.5			
Carcass weight (kg)	22.25	26.58	21.32	19.96	0.002	0.025	48.7, 2.80
Intramuscular fat (%)	0.44	0.75	0.79	0.79	0.37	0.33	8.2, 0.55
Steaks weight 60 °C (g)*	91.1	88.7	102.6	91.9	0.30	0.44	7.5, 17.9
Steaks weight 70 °C (g)*	88.0	88.1	101.6	88.5	0.28	0.49	9.7, 16.5

* Steaks used for cooking losses and tenderness measurements (25 mm thickness).

Table 2
Means of meat quality variables for male and female reindeer within adult and calf groups for measurements made on *M. longissimus lumborum*.

	Adult		Calf		Effect (P value)		R^2 (%), RSD
	Male	Female	Male	Female	Age	Gender	
24-hour drip loss (%)	1.47	1.72	0.66	1.27	0.075	0.25	16.3, 0.88
Expressed juice ($cm^2\ g^{-1}$)	35.6	36.7	34.7	35.0	0.40	0.60	4.0, 4.1
Cooking loss% (60 °C)	16.80	17.20	17.70	18.70	0.22	0.50	7.5, 2.48
Cooking loss% (70 °C)	26.13	27.14	25.98	24.46	0.06	0.80	20.8, 1.87
Sarcomere length (μm)	1.40	1.26	1.43	1.32	0.66	0.16	8.5, 0.25
Fibre diameter (μm)	40.2	42.2	38.6	39.3	0.24	0.38	8.3, 4.9
Ultimate pH	5.63	5.62	5.57	5.58	0.28	0.99	4.6, 0.12
Myofibrillar fragmentation index (MFI)	95.6	94.6	96.8	97.2	0.014	0.38	25.3, 1.8

Table 3
Means for colour measurements L*, a*, and b* after 30 min exposure for *M. longissimus* from male and female reindeer within adult and calf groups.

	Adult		Calf		Effect (P value)		R^2 (%), RSD
	Male	Female	Male	Female	Age	Gender	
L* (lightness)	35.2	33.7	36.1	35.8	0.031	0.092	25.9, 1.8
a* (redness)	8.99	8.09	10.25	10.11	0.002	0.17	35.5, 1.24
b* (yellowness)	−1.93	−1.82	−1.02	−0.60	0.011	0.56	23.5, 1.01
Chroma (intensity of colour)	9.26	8.40	10.34	10.15	0.002	0.12	35.7, 1.09
Oxy/Met (R630/R580)[a]	1.55	1.46	1.55	1.50	0.53	0.038	93.6, 0.13

For this variable only, a repeat measure analysis was used with data from the 4 times when assessments were made (Fig. 1).
[a] R630 nm/R580 nm indicate upper limit of oxymyoglobin at ~5 and upper limit of metmyoglobin at ~1.

(2007) found significantly higher levels of fat in muscles of hinds in comparison to stags. The very low amounts of intramuscular fat content compared to those of Wiklund et al. (2001) and Sampels (2005) may indicate lack of available food. Meat with this low intramuscular fat has only a small amount of fat as triglycerides (Sampels et al., 2004), with most fatty acids being typical of those in the phospholipids that are present mainly in cell membranes.

The steak weights are included in Table 1 to indicate that cross-sectional areas of muscles did not differ between groups. Only the carcass weights of calves appeared to be consistent with the weights of the Swedish reindeer reported by Wiklund et al. (2001) and Sampels et al. (2005). The adults examined here were smaller than Swedish reindeer that presumably also had grazed, but at a lower latitude (Wiklund et al., 2001; Sampels et al., 2005). The male group as opposed to the female group (Table 1) barely gained weight from the age of 6 months and this is partly due to lack of winter pasture but also due to a down-regulated appetite as a stress response (Reimers, 1983). It could also be influenced by poor summer nutrition and the efforts made at keeping a harem. January is also regarded as the time when adult males have a minimum weight. Finally, animals from Mid-Norway where the conditions are less harsh, may not necessarily be much heavier, but the meat will contain less protein including myoglobin and more fat (Maria Mielnik, personal communication).

3.2. Reindeer meat quality-related characteristics

No differences were found between genders regarding cooking loss or other variables shown in Table 2 associated with fibre/fibril characteristics. However, meat from adults had a lower myofibrillar fragmentation index, and tended to have higher losses after cooking at 70 °C than the meat from calves. Wiklund, Barnier, Smulders, Lundström, and Malmfors (1997) found for reindeer in Sweden that the sarcomere lengths varied substantially among individual animals, and reported values from 1.3 to 1.8 μm, which almost covers the range of values reported in Table 2.

For the colour parameters (L*, a*, b*, and chroma, Table 3) expected age differences were confirmed with meat from adult reindeer being darker, less red and less yellow. For some samples b* values were actually negative, particularly for adult samples, which is not common for uncooked meat. However, the b* values increased with time of air exposure (data not shown). Consistently low b* values (−3 or −1) for Norwegian reindeer meat have also been measured by Kvalvåg and Mielnik (personal communication). Visually reindeer meat is very dark (low L*) and has bluish shade/tint resulting in the negative values of yellowness (b*). Turkey breasts have been reported to have b* values down to −3. Low b* values have been found to occur more often in the summer for other species (Petracci, Betti, Bianchi, & Cavani, 2004).

3.3. Reindeer muscle composition

Gender differences were found for % haem iron with males having a higher percentage of haem iron (Table 5). Male adults tended to (P = 0.06) have a lower content of non-haem iron (results not shown). The taurine concentration was higher for calves than adults, with some tendency for carnosine to be higher for calves as well (Table 5). Carnosine tended to be higher for males, while anserine and vitamin E levels were not affected by age or gender. ARP was higher for meat from adults than calves. Significant differences were not observed between genders. However, Mielnik et al. (2007) suggested a higher antioxidant activity for Norwegian reindeer hinds and for muscle from northern regions. Taurine levels in meat from calves were at approximately the same level as in muscle from cod (Dragnes, Larsen, Ernstsen, Maehre, & Elvevoll, 2009). This is interesting as

Table 4
Means for male and female reindeer within adult and calf groups for measures of shear force made on *M. longissimus lumborum* samples cooked at either 60 °C or 70 °C.

	Adult		Calf		Effect (P value)		R^2 (%), RSD
	Male	Female	Male	Female	Age	Gender	
Samples cooked at 60 °C for 90 min							
WB*—Work done	10.3	14.7	5.5	4.1	<0.0001	0.08	58.8, 3.7
WB—Peak force (N)	42.4	47.5	14.8	11.3	<0.0001	0.65	60.7, 13.1
Samples cooked at 70 °C for 90 min							
WB—Work done	18.1	23.7	9.8	8.4	<0.0001	0.12	57.5, 5.6
WB—Peak force (N)	66.1	74.8	22.0	25.1	<0.0001	0.31	64.0, 18.1

* WB means Warner Bratzler shear force.

Table 5
Means for male and female reindeer within adult and calf groups for concentrations of selected nutrients and bioactive compounds in the *M. longissimus lumborum*.

	Adult		Calf		Effect (P value)		R^2 (%), RSD
	Male	Female	Male	Female	Age	Gender	
Total iron (mg/100 g)	4.40	4.66	4.30	4.55	0.55	0.15	9.1, 0.47
Haem iron (% of total Fe)	85.4	79.8	86.0	85.8	0.099	0.047	26.2, 5.0
Taurine (mg/100 g)	72.7	52.1	107.8	137.3	<0.0001	0.60	72.4, 20.4
Carnosine (mg/100 g)	303.1	275.3	350.3	304.6	0.071	0.09	20.8, 52.5
Anserine (mg/100 g)	194.0	200.9	187.8	205.9	0.95	0.27	5.7, 26.0
Vitamin E (mg/100 g)	0.602	0.518	0.498	0.538	0.53	0.51	6.1, 0.17
ARP* (mg DPPH/g meat)	0.46	0.58	0.42	0.36	0.02	0.20	23.2,0.13

* ARP means antiradical power.

seafood is generally regarded as having a high content of this organic acid. The higher contents in calves may be promoted by lactation and taurine contents in the milk. Carnosine values were close to the high and appreciated values observed in chicken breast (Crush, 1970); i.e. 270 mg/100 g. Vitamin E (here only α-tocopherol) levels have been reported to be 0.4–0.6 mg/100 g for meat from free-ranging reindeer in Sweden (Sampels et al., 2006) and, in agreement with the data in Table 5, no gender or age differences were observed by those authors.

3.4. Fatty acids in intramuscular fat of reindeer

Significant age differences were found for intramuscular fatty acid composition (Tables 6–8), with the calf group having higher levels of C17:0 (Table 6), and some monounsaturated fatty acids (C17:1) and total MUFA (Table 7), but lower levels of several polyunsaturated fatty acids including DPA, EPA, C20:4, and particularly C18:3 (Table 8). Few significant gender effects were found, but the male group had higher levels of both C17:0 and C17:1. Meat from male calves had the highest amount of SFA and MUFA and the lowest amount of PUFA compared to the other three groups (Table 8). Sampels et al. (2005) reported significant effects of age on SFA and MUFA contents with older animals being higher in SFA and lower in MUFA for neutral lipids for animals with more than 3% intramuscular fat. Age differences for polar lipids were less apparent, but C16:0 was higher in adults (Sampels et al., 2006). No such differences were observed in the current study (Table 6), assuming that the fatty acids were predominantly from polar lipids.

Table 6
Means for male and female reindeer within adult and calf groups for concentrations of saturated fatty acids (% of total FAs) in the *M. Longissimus lumborum*.

	Adult		Calf		Effect (P value)		R^2 (%), RSD
	Male	Female	Male	Female	Age	Gender	
C14:0 (myristic acid)	1.12	1.01	1.43	1.07	0.17	0.12	17.2, 0.34
C16:0 (palmitic acid)	20.14	19.55	22.75	19.45	0.28	0.17	15.2, 2.91
C17:0 (margaric acid)	1.09	0.92	1.28	1.12	0.028	0.047	27.3, 0.22
C18:0 (stearic acid)	19.04	19.18	20.41	19.72	0.31	0.88	4.8, 2.37

The reindeer for this project came from a natural grazing system, but resources were not available to record their feeds. It is not known whether the calves or adults received some grain-based concentrates, but based on the results of Sampels et al. (2006) with Swedish reindeer, the concentrations of C18:3 n−3 and the n−6:n−3 ratios given in Table 8 lend support to these animals being largely grazing animals (extensively fed) although limited intensive feeding cannot be ruled out.

3.5. Comparisons between meat from Norwegian reindeer and New Zealand farmed red deer

Above comparisons were made, when possible, to meat quality of Nordic extensively fed reindeer. A detailed comparison to New Zealand red deer meat (from Purchas et al., 2010), except for the ARP values that were not given in that paper, is also possible (Fig. 2). Gender groups were combined, even though gender effects have been found for a number of New Zealand farmed red deer variables. It is possible that better nurtured or older adult male reindeer might have given some support for the gender differences that were observed for the meat from red deer. Although the aim was to use similar methods and procedures in the research carried out in New Zealand on meat from red deer and in Norway on reindeer meat, there were some unavoidable differences (e.g. change of instrumentation) that could be partly responsible for the differences shown. In addition, the adult reindeer groups were more variable in age. These points need to be kept in mind when considering the results presented in Fig. 2 and the discussion below.

Selected differences between the reindeer meat and meat from NZ red deer are highlighted and discussed below:

1. Carcass characteristics: Apparently both Norwegian and Swedish reindeer weigh much less than NZ farmed red deer, which means that the weights of loins and cooked steaks will be less. The weight differences probably reflect species differences in mature weight primarily, but may also reflect the harsh nutrition conditions during the Norwegian winter. Intramuscular fat levels for reindeer at less than 1% were similar to those for venison from male red deer, but lower than those of the female red deer (Purchas et al., 2010).
2. Quality characteristics: Percentage drip losses over 24 h and expressed juice values were lower for reindeer meat than for red

Table 7
Means for male and female reindeer within adult and calf groups for concentrations of monounsaturated fatty acids (% of total FAs) in the *M. longissimus lumborum*.

	Adult		Calf		Effect (P value)		R^2 (%), RSD
	Male	Female	Male	Female	Age	Gender	
C14:1 (myristoleic acid)	0.25	0.23	0.34	0.39	0.17	0.99	7.8, 0.22
C16:1 (palmitoleic acid)	1.29	1.33	1.47	1.32	0.31	0.72	9.4, 0.20
C17:1 (cis-heptadecanoic acid)	0.23	0.21	0.32	0.25	0.04	0.27	20.6, 0.08
C18:1 t11 (trans vaccenic acid: TVA)	0.90	0.55	1.19	0.78	0.13	0.025	23.7, 0.43
C18:1 c9 (oleic acid)	24.74	25.90	29.18	27.62	0.091	0.88	12.5, 4.53
C18:1 c11 (cis-11-octadecanoic acid)	0.78	0.77	0.72	0.84	0.92	0.52	5.4, 0.15

Table 8
Means for male and female reindeer within adult and calf groups for concentrations of polyunsaturated fatty acids, groups of fatty acids (% of total FAs) and the ratios of P to S and of n−6 to n−3 fatty acids in the *M. longissimus lumborum*.

	Adult		Calf		Effect (P value)		R^2 (%), RSD
	Male	Female	Male	Female	Age	Gender	
C18:2 c6 (linoleic acid)	11.81	11.66	8.73	11.20	0.25	0.61	8.5, 3.87
C18:3 n−3 (α-linolenic acid)	1.41	1.11	0.63	0.80	0.007	0.76	26.0, 0.36
C20:4 n−6 (arachidonic acid)	6.36	6.17	3.22	5.40	0.044	0.36	19.3, 2.66
C20:5 n−3 (eicosapentaenoic acid, EPA)	1.22	1.19	0.62	0.85	0.012	0.73	23.7, 0.44
C22:5 n−3 (docosapentaenoic acid, DPA)	2.61	2.65	1.46	2.07	0.041	0.55	17.5, 1.04
C22:6 n−3 (docosahexaenoic acid, DHA)	0.15	0.13	0.12	0.11	0.36	0.50	4.9, 0.07
SFA[1]	41.4	40.6	45.9	41.4	0.22	0.32	11.7, 5.4
MUFA[1]	28.2	29.0	33.2	31.2	0.045	0.93	16.4, 4.4
PUFA[1]	23.3	23.4	14.8	20.4	0.08	0.53	14.6, 8.2
Polyunsaturated: Saturated FAs (PUFA/SFA)	0.61	0.60	0.32	0.54	0.14	0.53	12.4, 0.29
n−6 to n−3 ratio	3.67	3.63	4.24	4.23	0.0003	0.83	40.8, 0.36

[1] SFA, MUFA, PUFA = total saturated, monounsaturated, and polyunsaturated fatty acids, respectively.

deer venison, suggesting a higher water-holding capacity that may be partly due to the slightly higher ultimate pH (Fig. 2), but this was not reflected in lower cooking losses. Muscle fibre diameter (Fig. 2) was about 80% of those of venison, which may be a reflection of the smaller size of the species, although the relationship between muscle fibre diameter and size across species does not appear to be close (Rehfeldt, Stickland, Fiedler, & Wegner, 1999).

3. The reindeer meat had appreciably shorter sarcomeres (Fig. 2) than that of red deer meat, and myofibrillar fragmentation indexes (Fig. 2) were slightly lower, but values were still high for meat that had been aged for only 7 days.
4. Meat samples from reindeer calves were more tender than all other groups in terms of shear force values but these were similar for the other groups, except that the meat from male red deer had higher shear values (Table 4). The New Zealand red deer meat had significantly lower ultimate pH values than venison but all groups had satisfactorily low mean values (Fig. 2).
5. The colour parameter b* was significantly lower for reindeer meat than for red deer meat. It is unlikely that the low b* values reflected the low fat content of the muscle since red-deer meat had similar fat levels but higher and positive b* values, around 4 (Purchas et al., 2010). Fig. 1 (right panel) suggests that the rate of browning of red deer meat exposed to air gives an acceptable display period of one day, while, on average, reindeer meat had no acceptable display period at all with air exposure. Thus, this type of meat should be vacuumed or modified atmosphere (MAP) packed for all markets reacting negatively to brown meat. MAP preserved the colour of reindeer meat very well and provides stable L*, a* and b* values (Kvalvåg and Mielnik, personal communication). These low Oxy/Met ratios, which were appreciably lower than for red deer meat at each of the five times (Fig. 1), may be due to the endogenous metmyoglobin reductase system being less efficient in reindeer meat than for red deer meat, or to the ratio between myoglobin oxidation and reduction being higher.
6. Composition: The taurine content of reindeer meat was high, which may be looked upon as a positive trait by consumers. Total iron content of reindeer meat was also higher than in meat from red deer, with both meats having higher iron contents than found for beef and lamb (Forbes & Swift, 1925), but the proportion of haem iron to total iron was similar among the two groups of deer.
7. Fatty acid composition: The n−6:/n−3 fatty acid ratio was less favourable for reindeer meat compared to red deer meat. A n−6/n−3 ratio of 2 or below as for the New Zealand deer is typical for pasture-finished deer (Purchas et al., 2010). Also the C18:3, n−3 level was significantly lower for meat from reindeer than red deer probably because of dietary differences.

3.5.1. General discussion

The standard deviation of variables will reflect how homogenous the groups were, assuming similar analytical accuracy. Percentage of haem iron and vitamin E differed the most within each adult group (not shown) of Norwegian reindeer relative to the farmed red deer from New Zealand. The larger variation in these two variables may also affect colour stability in a negative way for reindeer. The smaller muscle fibres and darker colour of reindeer meat suggest that the

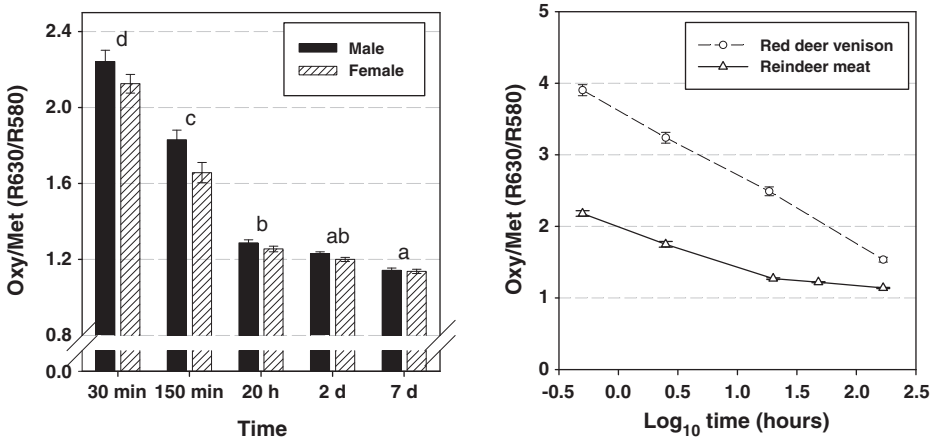

Fig. 1. Left:Means (±SE) showing changes in the relative ratio of oxymyoglobin to metmyoglobin (as assessed by the ratio of R630 to R580) when fresh cuts were exposed to air for up to 7 days. Pairs of bars without a common letter above them differ significantly ($P<0.05$). The male/female difference was significant at 150 min only ($P<0.05$). The graph on the right shows the extent to which the Oxy/Met (means ± SE) was lower for reindeer meat than red deer during aerobic storage.

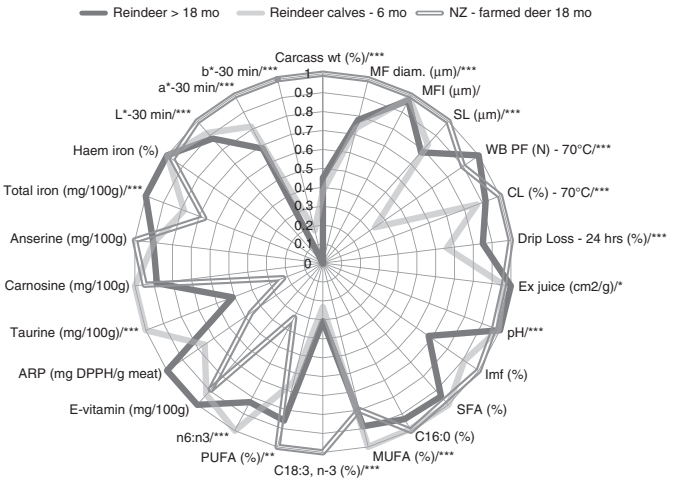

Fig. 2. Web drawing of selected variables measured on Norwegian reindeer meat and the corresponding measurements for meat from New Zealand farmed red deer. In order to obtain the web, each variable was transformed so that the group having the highest value for a specific variable was set at 1.0 on the radial scale and values for the other two groups were expressed relative to that. The colour variable b* was scale shifted to avoid negative values in the web. P values (*P<0.05; **=P<0.01; ***=P<0.001).

proportion of type I fibres may have been higher. It is noted that despite the high iron content (mostly haem iron) of reindeer meat, two Nordic reports (Wiklund et al., 1989; Ringstad et al., 1991) have indicated that the hitherto low incidences of cancer among Sami-people were related to their high consumption of reindeer meat. Even colon cancer seemed reduced in this group (Wiklund, Holm, & Eklund, 1989).

4. Conclusions

Meat from the loin of reindeer from Kautokeino in Norway was very tender, regardless of age and had good water binding properties. It had very low levels of intramuscular fat and high iron levels (more than 80% of which was haem iron). Iron levels were higher than reported for most other meats. Reindeer meat had good antioxidant capacity, but its colour stability was poor causing rapid browning when exposed to air. The meat contained significant concentrations of taurine, carnosine and anserine, with taurine levels being particularly high in meat from six-month old calves.

Loin (*M. longissimus lumborum*) from reindeer was similar to the same muscle of New Zealand red deer in being a tender, low fat product with high levels of haem and total iron. In this study the taurine levels were higher in reindeer meat (particularly for reindeer calves) than in meat from red deer, but the colour stability was poorer, and the n−6 to n−3 fatty acid ratio was less acceptable, possibly due to diet differences.

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