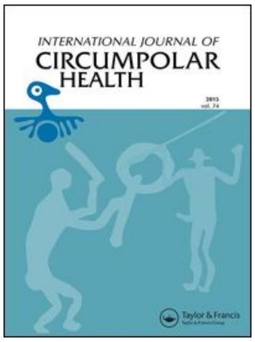

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ORIGINAL RESEARCH ARTICLE

Level of selected nutrients in meat, liver, tallow and bone marrow from semi-domesticated reindeer *(Rangifer t. tarandus L.)*

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Objectives: To acquire new knowledge on the nutritional composition of semi-domesticated reindeer *(Rangifer t. tarandus L.)* and their nutritional value for humans. The results could be useful in updating the Norwegian Food Composition Database, whose current data on reindeer is limited.

Study design: Cross-sectional study on population of semi-domesticated reindeer from 2 northern Norwegian counties (Finnmark and Nordland).

Methods: Semi-domesticated reindeer carcasses ($n = 31$) were randomly selected, from which meat, liver, tallow and bone marrow samples were collected. Selected vitamins, minerals, fatty acids and total lipids were studied.

Results: As expected, reindeer meat was found to be lean (2% total lipid), thus it is a good source of low-fat meat. The meat was also found to be a good source of vitamin B12, docosapentaenoic acid (C22:5 n-3) and α-linolenic acid (C18:3 n-3). Statistically significant differences ($p < 0.05$) in most of the nutrient levels between meat and the rest of the studied reindeer tissues were observed. In most cases, the liver, tallow and bone marrow had higher nutritional values when compared to meat. Liver had the highest concentrations of vitamin A, all vitamin B types, vitamin C, iron, selenium and the total amount of polyunsaturated fatty acids (n-3). Additionally, liver was the only edible tissue that contained vita-mins B9 and C. The vast majority of the vitamin concentrations in liver, tallow and bone marrow were significantly correlated with the concentrations in meat ($p < 0.05$).

Conclusions: The studied tissues from reindeer demonstrated that reindeer is a valuable food source that could meet or contribute to the consumers' nutritional recommended daily allowance (RDA).

Keywords: *Nutrients*; *edible tissues*; *reindeer*; *Sami*; *Norway.*

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Data on the meat composition of reindeer and caribou are very limited in comparison to other meat types and are mostly restricted to unpublished data such as local reports. Consequently, the Norwegian Food Composition Database lacks information on some levels for the nutri-tional elements of reindeer meat and meat products (1,2). Semi-domesticated reindeer (*Rangifer t. tarandus L.*) liver, tallow and bone marrow are important nutritional food substances in the traditional Sami diet.

The Sami are an Indigenous people and an ethnic minority in northern Fenno-Scandinavia and the Kola Peninsula in Russia. The greatest proportion of the total Sami population lives in Norway. Semi-domesticated reindeer are a fundamental component in sustaining the Sami culture, as well as an important food substance. The total number of reindeer in Norway is reported to be approximately 243,200, with the highest concentration in Finnmark County, the northernmost county in Norway, which has over 50% of the total amount (3). However, the

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numbers of reindeer and caribou herds are declining across the circumpolar region due to global climate change and modernization (4). The flock structure varies by district, and appears to be dominated by female reindeer at 69–78%, followed by calves at 17–21% and males at 4–11% (3).

Unlike cattle, the semi-domesticated reindeer in Norway primarily graze on a natural pasture throughout the year, of which a large number of species of vascular plants and lichens are the main component (5). However, some supplement feed such as dried hay and pellet concentrates may also sometimes be provided by owners during harsh winters when the natural pasture is inaccessible. Generally speaking, summer grazing is necessary for reindeer, as the green pasture is rich in proteins, minerals and cellulose and provides a reserve that can be used in winters during which carbohydrate-rich lichens are the main type of feed. This also allows reindeer to be in better physical condition in autumn than in spring when most of their reserves are depleted. Seasonal variations and animal feed types were reported to influence the varying nutritional composition of the reindeer meat and other edible tissues (6,7). The movement of reindeer herds through mountains, forests and plains differentiates their grazing habits from other Norwegian ruminants that are fed while indoors in the winter and outdoors on farmyards in the spring and autumn. Norwegian sheep are an exception since their free grazing in summer very much resembles that of the reindeer.

Semi-domesticated reindeer slaughterhouses are small in size and limited in capacity with line speeds varying between 20 and 60 carcasses per hour, depending on the structure of the slaugh-terhouse in comparison to other red meat slaugh-terhouses in Norway. In addition to the stationary slaughterhouses, there are a few mobile ones that contribute to the slaughter of a limited number of reindeer. The majority (69%) of slaughtered reindeer are calves, which are approximately 6–10 months old (3). The reindeer slaughtering season starts in early September and ends in late January of the following year.

Traditional foods for Indigenous people were reported to be the main sources of protein, fat, most minerals, vitamin D and long-chain n-3 fatty acids (8). In general, the nutritional values of meat vary in relation to many factors such as feed types, anatomy, species and animal physiology. The level of minerals, trace elements and vitamin B were reported to be much higher in reindeer meat than in cattle and pig meat (7). Studies on minerals in reindeer and other rumi-nants revealed a higher selenium concentration in the internal organs of reindeer 9–11, and the total lipid content in reindeer meat was reported to be low in comparison to other meat types (7,12,13).

The main purpose of this study was to obtain new knowledge on the nutrient value of semi-domesticated reindeer through the measurement of levels of selected vitamins, minerals, fatty acids and total lipids in the meat, liver, tallow and bone marrow. Our intent was to compare the nutrient value of reindeer meat, liver, tallow and bone marrow with the same from other species. Additionally, we wanted to also compare our results on reindeer meat, liver, tallow and bone marrow to consumers' nutritional recommended daily allowance (RDA). Hopefully, our results will be useful in updating the Norwegian Food Compo-sition Database, whose current data on reindeer is limited.

Materials and methods

Sample collection

Muscle, liver, tallow and bone marrow samples were randomly collected from semi-domesticated reindeer carcasses ($n = 31$ animals) from 7 districts in Finnmark ($n = 6$) and Nordland ($n = 1$) Counties in northern Norway. The selec-tion of the 2 counties was based on the fact that Finnmark has the largest number of semi-domes-ticated reindeer, while Nordland was chosen to provide a sample of the possible geographical variation in the concentration of nutrients. The average age of the reindeer from which the samples were collected from September 2004 to January 2005 was 1.5 years old, according to internal procedures (not published). However, a limited number of calves (approximately 6–10 months old, $n = 6$) and adult animals (over 2 years old, $n = 3$) had to be chosen because of a scarcity of slaughtered animals with the age of 1.5 years. Meat samples were collected from the muscles in the dorsal neck region. Liver samples were collected from the main loop, tallow was collected from the fat tissue surrounding kidneys, and bone marrow was collected from the hind and front legs. All of the samples were collected in pre-marked plastic bags immediately after the slaughter/dressing/carcass weighing process and then divided into different sample glasses/ plastic boxes. Each glass/plastic box was then labelled with the sample type, carcass number, district name/number and date of sample collection. Samples were put on ice (approximately 4°C) immediately after collection and distribu-tion into dedicated containers and kept frozen at -20°C (within 12 hours from the sample collec-tion) until analysis. Samples for vitamin analysis were stored in a -70°C freezer until they were shipped frozen to the laboratory for analysis. Glasses with samples for vitamin analysis were covered with aluminium foil to prevent them from being exposed to light. Hygienic measures were taken during the sample collection to avoid the possible microbiological contamination of samples.

Due to the high cost of vitamin analysis, pooled samples of meat, liver, tallow and bone marrow from the same district (a maximum of 5 animals of mixed age in a pooled sample) were prepared.

Laboratory analyses

The analyses of vitamins were conducted by GBA-Food (Hamburg, Germany) according to methods approved by the German Food Act LMBG § 35, LFGB § 64 and the standard methods of the Association of Official Analytical Chemists (14,15). The laboratory is accredited with the methods used in the analyses according to Staatliche Akktreditierungsstelle Hanover, AKS-P-20213-EU.

For mineral analyses, the meat and internal organs of reindeer were separately digested using a microwave oven technique. In short, concentrated supra-pure HNO3 (5 ml) and H2O2 (3 ml) were added to the sample (0.6–0.7 g) before undergoing the microwave oven treatment. Hence, the following temperature regimes were used in the microwave: 20–50°C (5 min.), 50–100°C (10 min.), 100–180°C (5 min.) and 180°C (15 min.). After cooling down the heated decomposed sample, the solution was diluted to 50 ml. The sample solution was analysed using an inductively coupled plasma high-resolution mass spectrometer (ICP-HRMS), Thermo Scientific Finnigan Element-2, Germany. All standards and calibration solutions contained 1 ppb Rhenium (Re) as an internal standard and 1% nitric acid (HNO3). The calibration curve was verified by use of a standard quality control (QC) sample, National Institute of Standards and Technology (NIST), USA. The resolutions used for minerals were low (at 10) for (Zn), middle (at 20) for (Ca, Fe), and high (at 30) for (Se). The lens adjustment was optimized daily to ensure maximum intensity and top separation.

Precautionary measures, such as the use of closed cabinet, non-metal sampling devices, tools and containers, were taken when preparing the decomposed samples to avoid contamination by dust or from mineral alloys in laboratory tools.

The analyses of fatty acids and total lipids were undertaken by Unilab Analyse A/S in the Fram Centre, Tromsø, Norway, according to a method for the isolation and purification of total lipids from animal tissues by Folch et al. (16). The laboratory is accredited for the methods used in the analyses according to the European standard NS-EN ISO/IEC 17025. Fatty acids are described by a shorthand nomenclature of chain length (number of carbon atoms): the number of double bonds and n-x which indicate the position of the last double bond related to the terminal methyl end. Additionally, common fatty acids names are used in polyunsaturated fatty acids.

Statistical analyses

Results were presented as mean values ± standard deviation (SD). The data set was entered in Excel® 2003 for Windows. Analytical results for vita-mins, minerals and fatty acids below the limits of detection (LOD) were replaced by zero, with the data then transferred to Stata/SE 11.0 for Windows (Stata Corp. College Station, TX) for further statistical analyses. Summary statistics was used to determine the mean, SD, minimum and maximum values. A dependent-sample t-test was used to test differences in the concen-trations of nutrient concentrations between meat and the other studied tissues. The differ-ences in fatty acid concentrations were only tested between meat and liver due to a small number of observations ($n = 3$) for tallow and bone marrow. A Pearson's correlation test was used to test for possible statistically significant correlations of nutrient concentrations between meat and the other studied tissues. The level of statistical significance was set at $p < 0.05$ for all performed analyses.

Ethics

The study did not include any living animals, did not have any adverse environmental health effects, with samples collected from reindeers that had been slaughtered for human consump-tion. Animals were fixed prior to slaughter, made unconscious using a bolt pistol and put down under the inspection of an official veterinarian according to Norwegian regulations on animal welfare in slaughterhouses (17).

RESULTS

Vitamins

Mean vitamin concentrations (per 100 g edible raw tissue) in meat, liver, tallow and bone marrow are shown in Table I.

Vitamins D2 and D3 were neither detected in meat nor in any of the studied tissues. Vitamins B9 and C were only detected in the liver, but as expected the liver had the highest concentration of vitamin B9 in relation to the meat, tallow and bone marrow. Vitamin A was the only vitamin found to reveal a large variation in concentrations among the 4 studied edible raw tissues (Table I), although the variation was harmonic in the districts from where the samples were collected (data not shown). The meat, liver and tallow samples had the same mean concentration of 0.48 µg/100g for vitamin E, while bone marrow had a 4 times higher ($p < 0.01$) concentration for this vitamin.

The majority of vitamin concentrations in liver, tallow and bone marrow were signifi-cantly correlated with concentrations in meat as shown: Vitamin A: meat-liver ($r = -0.95$, $p < 0.01$) and meat-tallow ($r = -0.90$, $p < 0.01$). Vitamin B1: meat-liver ($r = 0.99$, $p < 0.01$), meat-tallow ($r = 0.55$, $p < 0.05$) and meat-bone marrow ($r = 1.0$, $p < 0.01$). Vitamin B2: meat-bone marrow ($r = 1.0$, $p < 0.01$). Vitamin B3: meat-tallow ($r = 0.99$, $p < 0.01$). Vitamin B5: meat-tallow ($r = 0.90$, $p < 0.01$)

Table I. Mean vitamin concentrations in meat, liver, tallow and bone marrow of reindeer per 100 g of edible raw tissue

Vitamin	Meat (n = 20) Mean ± SD	Liver (n = 20) Mean ± SD	Tallow (n = 15) Mean ± SD	Bone marrow (n = 10) Mean ± SD	RDA[c] Female	Male	
Vitamin A (RAE)	19.93 ± 22.55	20915.5 ± 5310.22**	117 ± 22.98**	45.25 ± 47.70	700	900	RAE[b]
Vitamin B1 (mg)	0.09 ± 0.07	0.33 ± 0.30**	0.03 ± 0.02**	0.02 ± 0.02**	1.1	1.4	mg
Vitamin B2 (mg)	0.26 ± 0.07	2.63 ± 0.15**	0.15 ± 0.04**	0.51 ± 0.46*	1.3	1.7	mg
Vitamin B3 (mg)	4.28 ± 0.51	14.9 ± 4.77**	1.67 ± 1.22 **	n.d.[a] (<0.2 mg)	15	19	mg
Vitamin B5 (mg)	1.14 ± 1.23	5.85 ± 1.25**	0.41 ± 0.36**	0.18 ± 0.03**	–	–	
Vitamin B6 (mg)	0.19 ± 0.04	0.53 ± 0.08**	0.02 ± 0.03**	n.d.[a] (<0.05 μg)	1.2	1.6	mg
Vitamin B7 (μg)	1.23 ± 1.03	19.45 ± 7.88**	4.3 ± 3.48**	0.29 ± 0.31*	–	–	
Vitamin B9 (μg)	n.d.[a] (<2 μg)	302.78 ± 184.52	n.d.[a] (<2 μg)	n.d.[a] (<2 μg)	300	300	μg
Vitamin B12 (μg)	3.34 ± 1.83	161.73 ± 48.48**	2.23 ± 1.64**	1.24 ± 0.59*	2	2	μg
Vitamin C (mg)	n.d.[a] (<0.1 μg)	11.88 ± 12.93	n.d.[a] (<0.1 μg)	n.d.[a] (<0.1 μg)	75	75	mg
Vitamin D2 (μg)	n.d.[a] (<0.5 μg)	n.d.[a] (<0.5 μg)	n.d.[a] (<0.1 μg)	n.d.[a] (<0.1 μg)	7.5	7.5	μg
Vitamin D3 (μg)	n.d.[a] (<0.5 μg)	n.d.[a] (<0.5 μg)	n.d.[a] (<0.5 μg)	n.d.[a] (<0.5 μg)			
Vitamin E (mg)	0.48 ± 0.30	0.48 ± 0.20	0.46 ± 0.07	2.25 ± 0.47**	8	10	α-TE

[a]n.d. = Not detected (below the limit of detection).
[b]RAE = Retinol activity equivalent (μg).
[c]Recommended daily allowance (RDA) for adult males and females based on Nordic nutritional recommendations (28).
α-TE = α-Tocopherol equivalent (mg).
*Concentrations were significantly different from those in meat ($p < 0.05$).
**Concentrations were significantly different from those in meat ($p < 0.01$).

and meat-bone marrow ($r = 1.0$, $p < 0.01$). Vitamin B6: meat-liver ($r = -0.57$, $p < 0.01$) and meat tallow ($r = -0.60$, $p < 0.05$). Vitamin B7: meat-liver ($r = -0.52$, $p < 0.05$) and meat-bone marrow ($r = 1.0$, $p < 0.01$). Vitamin B12: meat-liver ($r = 0.84$, $p < 0.01$), meat-tallow ($r = 0.93$, $p < 0.01$) and meat-bone marrow.

Minerals

Table II shows the mean mineral concentrations of μg/100 g for Se and mg/100 g of edible raw tissue for Ca, Fe and Zn.

The highest Ca concentration of 339.70 ± 277.30 mg/100 g was found in bone marrow ($p < 0.01$). The Ca concentrations in meat and tallow were comparable (5.40 ± 1.0 and 5.10 ± 2.10 mg/100 g, respectively). Liver appeared to be the best source of Fe in terms of mean concentration at 41.10 ± 21.70 mg/100 g ($p < 0.01$). There were no differences in the Fe concentrations of meat, tallow and bone marrow ($p = 0.25$), with the following concentrations: 3.30 ± 0.70, 4.10 ± 1.50 and 3.1 ± 1.30 mg/100 g. Liver also had the highest Se content of 48.70 ± 48.90 μg/100 g ($p < 0.01$). The Se concentrations in meat, liver, tallow and bone marrow (Table II) were characterized by varia-tions among districts and from animals within the same district (results not shown), with one animal demonstrating a remarkably high Se concen-tration (data not shown). These variations have resulted in standard deviations similar or higher than the mean concentration. The Zn in liver was the only mineral that was significantly correlated with meat ($r = 0.77$, $p < 0.01$).

Fatty acids and total lipids

Fatty acids and total lipids concentrations were given in g/100 g edible tissue. The concentra-tions of saturated fatty acids (SFA), monounsat-urated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) are shown in

Table II. Mean mineral concentrations per 100 g of edible raw tissue

Element	Mean ± SD Meat (n = 29)	Liver (n = 29)	Tallow (n = 15)	Bone marrow (n = 9)	RDA[a] Female	Male
Zn (mg)	6.8 ± 0.2	3.5 ± 1.7*	0.2 ± 0.1*	0.1 ± 0.1*	7 mg	9 mg
Ca (mg)	5.4 ± 1.0	6.4 ± 1.1*	5.1 ± 2.1	339.7 ± 277.3*	1 g	1 g
Fe (mg)	3.3 ± 0.7	41.1 ± 21.7*	4.1 ± 1.5	3.1 ± 1.3	15 mg	9 mg
Se (μg)	3.0 ± 3.2	48.7 ± 48.9*	0.8 ± 1.6	0.2 ± 0.5	40 μg	50 μg

[a]Recommended daily allowance (RDA) for adult males and females based on Nordic nutritional recommendations (28), the RDA for Ca is based on data from the USDA (29).
*Concentrations were significantly different from those in meat ($p < 0.01$).

Table III. Mean fatty acids concentration of reindeer meat, liver, tallow and bone marrow in 100g of edible raw tissue

Fatty acids	Mean ± SD Meat (n = 28)	Liver (n = 30)	Tallow (n = 3)	Bone marrow (n = 3)
Saturated (SFA)				
C14:0	0.02 ± 0.01	0.01 ± 0.001**	0.78 ± 0.38	0.68 ± 0.28
C15:0	0.01 ± 0.001	0.01 ± 0.002	0.07 ± 0.02	0.07 ± 0.02
C16:0	0.26 ± 0.10	0.80 ± 0.21**	15.57 ± 1.99	14.84 ± 1.65
C17:0	0.01 ± 0.01	0.05 ± 0.02**	0.89 ± 0.11	0.35 ± 0.06
C18:0	0.23 ± 0.05	0.81 ± 0.08**	19.26 ± 1.61	3.22 ± 0.46
C20:0	1.31 ± 0.003	0.01 ± 0.003**	0.22 ± 0.06	0.06 ± 0.01
C22:0	0.002 ± 0.001	0.01 ± 0.001**	0.02 ± 0.01	0.01 ± 0.001
C24:0	0.001 ± 0.001	0.01 ± 0.001**	0.02 ± 0.02	0.01 ± 0.001
ΣSFA	1.84 ± 0.16	1.62 ± 0.23	36.83 ± 3.66	19.24 ± 2.42
Monounsaturated (MUFA)				
C14:1	0.002 ± 0.001[a]	0.003 ± 0.002[a]	0.06 ± 0.03	0.94 ± 0.20
C14:1 n-5	0.002 ± 0.001[a]	0.001 ± 0.002[a]	–	–
C16:1 n-5	0.002 ± 0.001	0.003 ± 0.001	0.04 ± 0.01	0.31 ± 0.08
C16:1 n-7	0.02 ± 0.01	0.03 ± 0.02**	0.65 ± 0.12	7.54 ± 2.18
C16:1 n-9	0.01 ± 0.002	0.02 ± 0.01**	0.33 ± 0.04	0.19 ± 0.01
C17:1	0.003 ± 0.002	0.01 ± 0.004*	0.20 ± 0.02	0.52 ± 0.03
C18:1 n-7	0.01 ± 0.003	0.03 ± 0.01**	0.46 ± 0.06	1.99 ± 0.80
C18:1 n-9	0.37 ± 0.12	0.91 ± 0.30**	31.70 ± 3.48	35.44 ± 1.15
C20:1 n-7	0.004 ± 0.001	0.001 ± 0.001*	0.02 ± 0.01	0.02 ± 0.01
C20:1 n-9	0.002 ± 0.001	0.01 ± 0.002**	0.15 ± 0.05	0.13 ± 0.02
C21:1 n-11	0.003 ± 0.001[a]	n.d.	0.003 ± 0.001	–
C22:1 n-7	0.001 ± 0.0002	0.001 ± 0.001	n.d.	n.d.
C22:1 n-9	0.001 ± 0.0001[a]	0.0002 ± 0.0002*	n.d.	n.d.
C22:1 n-11	0.003 ± 0.001	0.002 ± 0.001**	0.003 ± 0.001	0.01 ± 0.01
C24:1 n-9	0.001 ± 0.0003	0.002 ± 0.001**	n.d.	n.d.
ΣMUFA	0.43 ± 1.14	1.02 ± 0.35	33.62 ± 3.83	47.10 ± 4.48
Polyunsaturated (PUFA)				
C16:2 n-7	0.0002 ± 0.0002	0.0002 ± 0.0004	0.01 ± 0.01	0.01 ± 0.004
C16:3 n-4	0.001 ± 0.001	0.003 ± 0.001**	n.d.	n.d.
C16:4 n-1	0.01 ± 0.004	0.02 ± 0.01	0.36 ± 0.07	0.33 ± 0.06
C18:3 n-3	0.01 ± 0.004	0.03 ± 0.01	0.04 ± 0.03	0.04 ± 0.01
C18:4 n-3	0.002 ± 0.001	0.003 ± 0.003**	0.02 ± 0.001	0.03 ± 0.02
C18:5 n-3	0.001 ± 0.001	0.01 ± 0.01*	0.03 ± 0.01	0.04 ± 0.02
C20:3 n-3	0.001 ± 0.0004	0.01 ± 0.003**	0.002 ± 0.002	0.01 ± 0.01
C20:4 n-3	0.001 ± 0.0002	0.002 ± 0.001**	0.01 ± 0.002	0.01 ± 0.003
C20:5 n-3	0.01 ± 0.004	0.03 ± 0.01	0.01 ± 0.002	0.01 ± 0.01

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Table III (Continued)

Fatty acids	Mean ± SD Meat (n = 28)	Liver (n = 30)	Tallow (n = 3)	Bone marrow (n = 3)
C22:5 n-3	0.04 ± 0.01	0.26 ± 0.09**	0.02 ± 0.01	0.03 ± 0.01
C22:6 n-3	0.003 ± 0.001	0.05 ± 0.02**	0.003 ± 0.001	n.d.
C18:2 n-6	0.15 ± 0.05	0.36 ± 0.06**	0.82 ± 0.19	0.67 ± 0.18
C18:3 n-6	0.0002 ± 0.0001	0.0002 ± 0.001	0.004 ± 0.001	0.01 ± 0.004
C20:2 n-6	0.002 ± 0.001	0.01 ± 0.002**	n.d.	n.d.
C20:3 n-6	0.01 ± 0.003	0.02 ± 0.01	0.01 ± 0.001	0.01 ± 0.002
C20:4 n-6	0.09 ± 0.04	0.42 ± 0.07**	0.11 ± 0.03	0.12 ± 0.04
C22:2 n-6	n.d.	n.d.	n.d.	n.d.
C22:4 n-6	0.01 ± 0.004	0.07 ± 0.02**	0.01 ± 0.002	0.004 ± 0.002
C22:5 n-6	0.0001 ± 0.0003	0.001 ± 0.001	0.01 ± 0.01	0.02 ± 0.01
ΣPUFA	0.34 ± 0.11	1.30 ± 0.17	1.47 ± 0.33	1.34 ± 0.14
ΣPUFA n-3	0.07 ± 0.02	0.40 ± 0.10	0.14 ± 0.05	0.17 ± 0.05
ΣPUFA n-6	0.26 ± 0.09	0.88 ± 0.12	0.96 ± 0.21	0.84 ± 0.14
ΣPUFA n-6/ ΣPUFA n-3	3.71 ± 0.003	2.20 ± 0.004	6.86 ± 0.10	4.94 ± 0.15

[a]Observations less than those given in the main column: Meat (n = 14) and liver (n = 17) for C14:1. Meat (n = 14) and liver (n = 13) for C14:1 n-5. Meat (n = 14) and liver (n = 13) for C14:1 n-5. Meat (n = 27) for C21:1 n-11. Meat (n = 27) for C22:1 n-9.
n.d = Not detected.
*Concentrations were significantly different from those in meat ($p < 0.05$).
**Concentrations were significantly different from those in meat ($p < 0.01$).

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Table III. Eight polyunsaturated fatty acids n-3 (PUFA n-3) were detected in the meat, liver and tallow, while 7 were detected in bone marrow.

Docosapentaenoic acid, DPA (C22:5 n-3) and α-linolenic acid, as well as ALA (C18:3 n-3), were detected in all studied reindeer tissues and had the highest concentrations among PUFA n-3 (Table III). Meat had the lowest concentration for PUFA n-3 among all the sample types.

Seven types of PUFA n-6 were found in the meat and liver, while 6 were found in the tallow and bone marrow. The highest concentration of PUFA n-6 was 0.15 ± 0.05 g/100 g in meat for linoleic acid (C18:2 n-6), followed by 0.42 ± 0.07 g/100 g in liver for arachidonic acid, AA (C20:4 n-6). Tallow and bone marrow had the lowest PUFA n-6 concentrations. The eicosapentaenoic acid, EPA (C20:5 n-3) concentrations in meat, liver, tallow and bone marrow were 0.01 ± 0.004, 0.03 ± 0.01, 0.01 ± 0.002 and 0.01 ± 0.01g/100 g, respectively. However, the docosahexaenoic acid, DHA (C22:6 n-3) concentrations in meat, liver and tallow were 0.003 ± 0.001, 0.05 ± 0.02 and 0.003 ± 0.001 g/100 g, respectively. The DHA was not detected in bone marrow samples. The ratios of n-6 to n-3 PUFA in meat, liver, tallow and bone marrow were 3.71 ± 0.003, 2.20 ± 0.004, 6.86 ± 0.10 and 4.94 ± 0.15 g/100 g, respectively.

The mean percentages (g/100 g) of the total lipid content in meat, liver, tallow and bone marrow were 2 ± 0.84 (n = 27), 5.64 ± 0.88 (n = 31), 78.89 ± 6.84 (n = 3) and 71.79 ± 15.99 (n = 3), respectively.

As expected, the results from Tables I, II and III revealed considerable differences in nutrient levels between the meat and the rest of the studied tissues. These differences were statistically signifi-cant ($p < 0.05$), except for the Se and Fe in tallow and bone marrow, the total lipid in tallow and bone marrow and the fatty acids C14:1, C14:1 n-5, C16:1 n-5, C16:1 n-7, C16:2 n-7, C16:4 n-1, C18:3 n-3, C18:3 n-6, C20:3 n-6, C20:5 n-3, C22:1 n-7, C22:5 n-6 in the meat and liver. In most cases, the liver, tallow and bone marrow had higher nutrient levels in comparison to meat ($p < 0.05$).

Significant correlations in fatty acid concentrations between meat and the other studied tissues were only detected between the meat and liver. The fatty acids that were significantly corre-lated were C16:3 n-4 ($r = -0.43$, $p < 0.05$), C18:1 n-7 ($r = 0.78$, $p < 0.01$), C18:2 n-6 ($r = 0.45$, $p < 0.05$), C22:4 n-6 ($r = 0.44$, $p < 0.05$) and C22:5 n-3 ($r = 0.48$, $p < 0.01$). No significant correlation was detected for total lipid content between the meat and liver. Moreover, the correlation was not tested between meat-tallow and meat-bone marrow due to the small number of animals (n = 3) included in the total lipid analysis of tallow and bone marrow.

Discussion

Meat from the semi-domesticated reindeer is lean and a good source of vitamin B12, docosapentaenoic acid (C22:5 n-3) and α-linolenic acid (C18:3 n-3). Statistically significant differences ($p < 0.05$) were observed in most of the nutrient levels between meat and the rest of the studied tissues. Liver had the highest concentrations of vitamin A, all vitamin B types, vitamin C, iron, selenium and the total amount of polyunsaturated fatty acids (n-3).

Additionally, liver was the only edible tissue that contained vitamins B9 and C. The vast majority of the vitamin concentrations in liver, tallow and bone marrow were significantly corre-lated with the concentrations in meat ($p < 0.05$). To the best of the authors' knowledge, this study is unique and the first of its kind to include a relatively large number of animals (31 reindeer) and to study nutrient concentrations from the meat, liver, tallow and bone marrow of semi-domesti-cated reindeer in Norway.

The mean concentration in the meat for vitamin B3 in this study is in agreement with Rastas (18). Still, our concentrations of vitamins B1, B2 and E were half the values in the referred study, whereas the vitamin A concentration was 3 times higher. Vitamins B9 and C in meat were not detected in our study, though their respective mean concentration (n = 24) has been formerly reported to be 2.6 and 3.3 μg/100 g (7). In agree-ment with a study by Nieminen (7), the meat and liver samples exhibited a similar mean value for vitamin E. However, concentrations reported in the same study for vitamins B1, B2 and B3 in meat were slightly higher with an exception for vitamin A, which was 3 times higher in our study. The liver contained higher vitamin concentrations than the meat, with the exception of vitamin E, which had a similar concentration in both sample types. The liver of reindeer, pork and cattle was also reported to be much richer in vitamins compared to meat (7). Although liver is rich in vitamin B9 (folic acid), it is difficult to find the entire amount in raw tissue when heated since cooking food at a high heat will reduce or demolish the amount of vitamin B9. Concentrations of vitamins B2, B3, B6 and B9 in caribou meat were reported to be 1.14 mg, 10.91 mg, 0.47 mg and 11.80 μg/100 g, respectively, while the concentrations of these vitamins in liver were found to be 1.58 mg, 15.64 mg, 1.97 mg and 374.30 μg/100 g, respectively. Furthermore, vitamin B2 and B6 concentrations in bone marrow have been reported to be 0.30 mg and 0.09 mg/100 g, respectively (19).

In one of the districts from which the samples were collected, vitamin A concentrations in meat and internal organs were much higher than in the other districts. The large variation in vitamin A in one district resulted in standard deviation that was higher than the mean concentrations in meat and bone marrow. Nonetheless, the variation in the vitamin A concentration in meat, liver, tallow and bone marrow in this district was harmonic, that is, it followed the same pattern for vitamin A in other districts in which the concentrations were the highest in liver, followed by tallow, bone marrow and meat.

The vitamin A mean concentrations in meat and liver were 19.93 ± 22.55 and 20915.50 ± 5310.22 RAE/100 g, respectively, in our study, whereas Nieminen's respective concentrations were 6.60 and 26000 RAE/100 g (7). The vitamin E concen-trations for meat, liver and tallow of caribou were found to be 0.15, 12.64 and 0.68 mg/100 g, respectively, while the respective vitamin A concentrations were 0.15, 12.64 and 0.68 mg/100 g (20). The concentration of vitamin D in our study was below the detection limits of all sample types. However, its concentration of 1.40 μg/100 g was only detected in the liver of caribou (20). The vitamin C concentration in the meat and liver of caribou were reported to be 0.86 and 23.76 mg/100 g, respectively (21).

The Se concentrations in meat, liver, tallow and bone marrow (Table II) were characterized by variations among both districts and in animals within the same district (results not shown). One animal had a remarkably high Se concentra-tion (data not presented). These variations have resulted in standard deviations which are similar or higher than the mean concentrations. The meat Se concentration in this study was 12.5% lower than the value of 24.0 μg/100 g reported elsewhere (7,18), whereas the liver Se concen-tration in our study was 5 times higher than the value of 10.0 μg/100 g reported by Fediuk et al. (21). The concentrations of meat and liver Ca, Zn and Fe in this study are comparable with those reported in previous studies on reindeer and caribou (7,18,21,22).

Even though most of our results on fatty acids in reindeer meat were 34% to 68% lower than those reported by Sampels et al. (12), the concentrations of docosapentaenoic acid, DPA (C22:5 n-3) and adrenic acid (C22:4 n-6) were in accordance with the same reference. Compared to Sampels et al. (12), the low results on fatty acids in the present study may be explained in part by the fact that the reindeer used by Sampels et al. were calves (about 10 months) that had been fed a pelleted feed mixture for two months prior to slaughter. The concentrations of fatty acids C18:2 n-6, C18:3 n-6, C18:3 n-3 and C18:4 n-3 in reindeer bone marrow reported by Soppela and Nieminen (23) were 2 to 19 times higher than those reported in our study, while the fatty acid C20:4 n-6 was twice as high in our study. Moreover, ΣPUFA n-3 and n-6 in bone marrow reported by Soppela and Nieminen (23) were twice as high than those found in our study.

It is a well-established fact that aquatic animals have higher concentrations of PUFA n-3 compared to terrestrial ones. Nevertheless, the PUFA n-3 concentrations of DPA and ALA in reindeer meat from this study are comparable to those formerly reported for DPA and ALA in crab, scampi, mussels and oysters and DPA in code (24). A study on turkey meat reported a DHA concentration comparable with our results for reindeer meat, whereas the concentrations of DPA and ALA were lower in turkey meat (25). Species, animal diet, environmental and genetic factors were reported to affect the fatty acid composition of meats (26).

The results for the low total lipid percentage in the present study from reindeer meat is in accordance with previous reindeer and caribou studies (7,12,13,21,22). With its lower fat content compared to domestic ruminants, this seems to indicate that reindeer meat can be considered an excellent source in meeting the consumer demand for low-fat meat. The total lipid percentage of rein-deer liver measured in this study is 5.64%, though the total lipid percentages in the liver of reindeer and caribou have formerly been reported to be 4% and 3%, respectively (7,21). The total meat lipid of wild ruminants was reported to be lower than that for domestic ruminants (27). Moreover, the total meat lipids in chickens and calves are comparable to those of reindeer, while turkey meat was reported to have a lower total meat lipid percentage (25).

Based on Nordic nutritional recommenda-tions (28), the concentration of nutrients in semi-domesticated reindeer meat, liver, tallow and bone marrow could meet or contribute to the recommended daily allowance (RDA), see Tables I, II, III. In addition, a ratio of n-6 to n-3 polyunsaturated fatty acids between 3 and 9 in the diet is considered to be sufficient in meeting the RDA (28). The ratios of ΣPUFA n-6/ ΣPUFA n-3 obtained from our study on meat, tallow and bone marrow fell between 3.71 and 6.87. The calculations for the contribution to the RDA done in this study were based on raw tissues; therefore, it is important to consider the impact of cooking since cooking will have an effect on the nutrient content.

The overview for the concentrations of some of the nutrients on reindeer meat and liver from this study, as well as the nutrient concentrations for the other meat and liver types presented in the Norwegian Food Composition Database (1), is shown in Table IV and V. In a similar manner, an overview of the nutrient concentrations on rein-deer meat from our study and the meat of other cervides (e.g. moose and roe deer) presented in the United States National Nutrient Database for Standard Reference (29) are listed in Table VI. Such overviews should be put in a nutritional context in terms of which meat type may be the best source for the specific nutrient, rather than in a comparative one. Species, animal diet, physi-ological and methodological variations need to be taken into consideration. The

Table IV. Mean vitamins, minerals and total lipid concentrations of reindeer meat and other meat types.

			Data from the Norwegian Foods Database[b]				
Nutrient*	Reindeer[a]	95%CI[a]	Lamb	Beef	Calves	Pork	Chicken
Vitamin A (RAE)	19.93	9.37–30.47	7.00	7.00	–	4.00	**11.00**
Vitamin B1 (mg)	0.09	0.05–0.12	**0.09**	0.03	**0.09**	0.42	0.14
Vitamin B2 (mg)	0.26	0.22–0.29	0.15	0.11	**0.22**	0.15	0.18
Vitamin B3 (mg)	4.28	4.04–4.51	6.00	4.10	5.10	5.10	7.80
Vitamin B5 (mg)	1.14	0.56–1.72	–	–	–	–	–
Vitamin B6 (mg)	0.19	0.17–0.21	0.16	0.15	0.40	0.23	0.38
Vitamin B7 (μg)	1.23	0.75–1.71	–	–	–	–	–
Vitamin B9 (μg)	<2.00	–	1.00	3.00	5.00	5.00	11.00
Vitamin B12 (μg)	3.34	2.48–4.20	1.30	1.00	1.30	0.50	0.40
Vitamin E (mg)	0.48	0.34–0.62	0.20	0.20	0.20	**0.60**	0.20
Zinc (mg)	6.80	5.90–7.71	2.30	3.40	4.30	2.40	1.20
Calcium (mg)	5.40	5.02–5.75	10.00	7.00	12.00	6.00	6.00
Iron (mg)	3.30	2.99–3.52	1.80	1.60	1.50	0.80	0.70
Selenium (μg)	3.00	1.79–4.28	**3.00**	**4.00**	6.00	10.00	13.00
Total lipid %	2.00	1.67–2.33	17.10	9.00	3.00	15.50	**2.10**

*Vitamins C, D2 and D3 in reindeer were below the limit of detections (LOD); their values in other animals were not given by the referred database (1).
[a]Results on reindeer meat from this study.
[b]Results based on data from the Norwegian Food Composition Database (1).
– = Not given.
Note: Values in **bold** are the ones that fall within a 95% CI for mean nutrients values of reindeer meat in this study.

Table V. Mean vitamins, minerals and total lipid concentrations per 100 g of raw reindeer liver and other raw liver types

			Data from the NFC Database[b]			
Nutrient	Reindeer[a]	95% CI[a]	Lamb	Cattle	Pig	Chicken
Vitamin A (RAE)	20915.50	18430.24–23400.76	32760	**23220**	23580	9702
Vitamin B1 (mg)	0.33	0.18–0.47	**0.39**	**0.30**	**0.43**	0.63
Vitamin B2 (mg)	2.63	2.55–2.70	3.49	2.79	2.86	3.40
Vitamin B3 (mg)	14.90	12.67–17.13	**14.00**	10.30	11.00	9.20
Vitamin B5 (mg)	5.85	5.26–6.44	–	–	–	–
Vitamin B6 (mg)	0.53	0.49–0.57	**0.53**	0.74	0.64	0.80
Vitamin B7 (μg)	19.45	15.76–23.14	–	–	–	–
Vitamin B9 (μg)	302.78	216.42–389.13	**281**	529	813	740
Vitamin B12 (μg)	161.73	139.03–184.42	114.00	200	30.00	21.00
Vitamin C (mg)	11.88	5.83–17.92	20.00	25.00	**15.00**	34.00
Vitamin D2 (μg)	<0.50		0.50	1.70	1.10	0.20
Vitamin D3 (μg)	<0.50		0.50	1.70	1.10	0.20
Vitamin E (mg)	0.48	0.39–0.57	1.50	1.30	1.50	0.20
Zinc (mg)	3.50	2.80–4.11	**3.90**	**3.80**	8.70	2.40
Calcium (mg)	6.40	6.02–6.85	5.00	4.00	5.00	7.00
Iron (mg)	41.10	32.84–49.34	9.60	7.40	18.70	7.30
Selenium (μg)	48.70	30.07–67.24	24.00	15.00	**46.00**	**44.00**
Total lipid %	5.64	5.32–5.97	4.10	3.20	3.40	3.80

[a]Results on reindeer liver from this study.
[b]Results based on data from the Norwegian Food Composition (NFC) Database (1).
– = Not given.
Note: Values in **bold** are the ones that fall within a 95% CI for the mean nutrient values of reindeer liver in this study.

Table VI. Mean vitamins, minerals and total lipid concentrations of reindeer meat and other related species meat

		Data from the USDA National Nutrient Database[b]			
Nutrient*	Reindeer[a]	Caribou	Deer	Moose	Antelope
Vitamin A (RAE)	19.93	0.0	0.0	0.0	0.0
Vitamin B1 (mg)	0.09	0.32	0.22	**0.07**	0.30
Vitamin B2 (mg)	0.26	0.72	0.48	**0.24**	0.60
Vitamin B3 (mg)	4.28	5.50	6.37	5.00	–
Vitamin B5 (mg)	1.14	2.50	–	–	–
Vitamin B6 (mg)	0.19	0.37	0.37	–	–
Vitamin B7 (μg)		1.23	–	–	–
Vitamin B9 (μg)	<2.00	4.00	4.00	–	–
Vitamin B12 (μg)	3.34	6.31	6.31	–	–
Vitamin C (mg)	<0.10	0.0	0.0	4.00	0.0
Vitamin E (mg)	0.48	–	0.20	–	–
Zinc (mg)	6.80	4.00	2.09	2.80	1.30
Calcium (mg)	5.40	17.00	5.00	5.00	3.00
Iron (mg)	3.30	4.69	**3.40**	**3.28**	**3.20**
Selenium (μg)	3.00	10.20	9.70	–	9.70
Total lipid %	2.00	3.36	2.42	1.50	**2.00**

*Vitamins D2 and D3 in reindeer were below the limit of detections (LOD); their values in other related species were not given by the referred database (29).
[a]Results on reindeer meat from this study, a 95% CI were given in Table V.
[b]Results based on data from the USDA National Nutrient Database (29).
– = Missing or incomplete value.
Note: Values in **bold** are the ones that fall within a 95% CI for mean nutrient values of reindeer meat in this study.

nutrient values, which are written in bold for other meat and liver types (Table IV, Table V and Table VI), fell within the 95% confidence interval for the mean nutrient values of reindeer meat and liver in this study. As a result, the nutrient values in bold did not differ from those values obtained on reindeer meat and liver. The opposite was true for the data on other meat and liver types not written in bold, as they differ from the values obtained from our study. Furthermore, it was difficult to say something about whether these differences were statistically significant or not since neither confidence intervals nor standard deviations were available on the referred data used in the overview.

There was a scarcity of slaughtered animals aged 1.5 years; thus we were compelled to choose animals (30%, n = 9) out of the protocol scope (20%, n = 6 claves and 10%, n = 3 adult animals). The deviation made by choosing animals (30%) out of the protocol age scope may influence the mean nutrient value if nutrient levels tend to be age dependent. Nevertheless, our raw data revealed little or no varia-tion in nutrient concentrations among the 31 animals. The vitamin levels of reindeer calves were reported to be higher (7–10%) than those of adult animals (7,30).

The vitamin analysis in meat, liver, tallow and bone marrow was based on the pooled sample. The advantage of the pooled sample is that fewer samples have to be analysed, thereby being a time-saving and cost-beneficial method. The disadvantage is that the individual nutrient concentration is based on the combined concentration of all animals in the pooled sample, and cannot be obtained for each animal on an individual basis. Hence, all the animals in the specific pooled sample received the same nutrient concentration.

The bone marrow samples were very limited, and varied in relation to the number of different laboratory analyses types conducted in this study (see Tables I, II and III). This was due to practical reasons around the sample collection and an insufficient sample quantity. Consequently, concentrations of fatty acids on tallow and bone marrow (n = 3 animals) may only be indicative.

In conclusion, the study provided information about the nutrient quality of reindeer meat, liver, tallow and bone marrow. The judge-ment as to whether nutrient concentrations are high or good sources for humans was based on how much these nutrients may contribute to the recommended daily allowance (RDA). Semi-domesticated reindeer meat is lean, thus it suit-ably meets consumers' need for low-fat meat, and meat is also a good source of vitamin B12, docos-apentaenoic acid (DPA) and α-linolenic acid (ALA). In addition, reindeer liver contains high concentrations of vitamins A, B9, B12, Fe and Se. The ratios of ΣPUFA n-6/ ΣPUFA n-3 in meat, tallow and bone marrow are high enough to cover

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the RDA. The tallow contains a high concentration of vitamin B12, while bone marrow contains the highest concentrations of vitamin E and Ca. The presence of reindeer meat, liver, tallow and bone marrow in a meal is a good approach for meeting or contributing to consumers' nutrient RDA needs. The vast majority of nutrient concen-trations in reindeer liver, tallow and bone marrow were significantly ($p < 0.05$) different from the concentrations in meat (mostly higher than those found in meat). Most vitamin concentrations in liver, tallow and bone marrow were signifi-cantly correlated with the concentrations in meat ($p < 0.05$).

Further research, which includes more animals from many different grazing districts, is needed to take into account factors that we could not investigate in this study, such as geographical variations, in order to look into their association to the nutrient composition of reindeer.

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