Influence of production system, age and sex on carcass parameters and some biochemical meat quality characteristics of reindeer (*Rangifer tarandus tarandus* L.)

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Abstract: Carcass composition in reindeer is affected by feed intake and the age and sex of the animal. Studies have also shown that age, sex, carcass trim fat content and total intramuscular fat content (IMF) influence lipid class composition. The aim of this study was to compare lipid class composition and IMF in relation to carcass weight, conformation and trim fat content, and to investigate how these parameters are affected by age, sex and different feed sources. Five groups of reindeer were studied. Two groups of calves were fed two grain-based pelleted feeds with different lipid compositions for approximately two months before slaughter. One of these groups was fed with conventional pellets, and the other with pellets enriched with linseed cake to increase the amount of n-3 fatty acids in the diet. Three groups of grazing reindeer were also included in the study, consisting of adult males, adult females or calves. Reindeer calves fed pellets had higher slaughter weights, higher trim fat content and better carcass conformation scores compared to the grazing calves. However, there was no significant difference in IMF between pellet-fed and grazing calves. Adult female reindeer had the highest and grazing calves the lowest slaughter weights, trim fat and IMF. There was no difference in lipid class composition in meat from calves fed with the two pelleted feeds, whereas grazing calves had a higher amount of phospholipids. Squalene was identified and quantified as a component of intramuscular lipids in reindeer meat.

Key words: animal nutrition, human nutrition, lipid classes, pasture, squalene.

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Introduction

Reindeer (*Rangifer tarandus tarandus*) are the northernmost freely ranging ruminant in Scandinavia, and are well adapted to a habitat with a cold climate and snow for the majority of the year. In summer, the diet is rich, consisting of fresh grass, sedges, shrubs and herbs, whereas in the autumn it changes gradually to include mostly lichens and dwarf shrubs (Eriksson *et al.*, 1981; Nieminen & Heiskari, 1989) and during the winter months November-March (the traditional slaughter season) the natural food supply is limited and reindeer on pasture do not normally gain weight (Reimers, 1983).

Since the nuclear accident in Chernobyl in 1986, the main reason for feeding reindeer grain-based pellets before slaughter has been to reduce levels of radioactive caesium in the meat (Åhman, 1999). However, supplementary feeding may also improve the animals' nutritional status in terms of increased intramuscular fat content (IMF) and higher body weight (Jacobsen *et al.*, 1977), since severe winter conditions allow limited access to forage (Helle, 1984).

Sexual segregation and differences between the metabolic strategy of males and females in deer and other ungulates have been reported (Pérez-Barbería & Gordon, 1999; Barboza & Bowyer, 2000)

and lead to different amounts of IMF in male and female animals. These are probably important factors for the reindeer's survival and reproduction, since sexual segregation and differences in growth and subcutaneous fat deposition between adult females and reindeer calves have been shown (Adamczewski *et al.*, 1987; Chetkiewicz *et al.*, 1991).

Higher IMF leads to a higher proportion of triacylglycerols (TAG) (storage lipids) and a lower proportion of phospholipids (Marmer *et al.*, 1984; Sinclair & O'Dea, 1990) in muscle. As phospholipids are usually richer in polyunsaturated fatty acids (PUFA) compared to TAG (Sinclair & O'Dea, 1990; Scollan *et al.*, 2001), the knowledge about the proportions of TAG to phospholipids adds important information about meat quality. Changes in fatty acid composition in reindeer meat due to age, sex and diet have been reported in an earlier study (Sampels, 2005).

Table 1. Industrial nutrient analyses for the pelleted feeds (Renfor Bas and Renfor Bas enriched with crushed linseed) (Lantmännen, 2003)

Nutrient content	Renfor Bas (CPD)[1]	Renfor Bas plus linseed (LPD)[2]
Crude protein, %	10.0	10.4
Energy, MJ/kg	10.0	10.0
Fibre, %	15	14.6
Crude fat, %	3.0	3.05
Water, %	12.0	12.0
Vitamin A, IU/kg	9000 (2.7mg/kg)	9000 (2.7mg/kg)
Vitamin D_3, IU/kg	3000 (0.075 mg/kg)	3000 (0.075 mg/kg)
Vitamin E, mg/kg	60	60
Calcium, %	0.8	0.8
Phosphate, %	0.4	0.4
Magnesium, %	0.3	0.3
Selenium, %	0.6	0.6

[1] Diet of conventional pellets.
[2] Pellets enriched with linseed cake.

The present study extends the earlier work by focusing on the relationship between the nutritional status of the reindeer and nutritional aspects of meat quality. The aim was to analyse lipid class composition and IMF in relation to trim fat, carcass weight and conformation, and to investigate how these parameters are affected by age, sex and different feed sources.

It is known that minor components of the diet, such as plant sterols or phenolic compounds, can affect consumer health (Parr & Bolwell, 2000; Piironen *et al.*, 2000; Ostlund *et al.*, 2002), and thus we also aimed to identify an unknown substance found in the neutral lipid (NL) fraction of reindeer meat during fatty acid analyses (Sampels, 2005).

Material and methods

Animals

A total of 38 reindeer (seven males and seven females aged 2-3 years, and 24 calves aged about 10 months) were studied. In an earlier study (Sampels *et al.*, 2004) no differences in slaughter weights, carcass composition, trim fat and lipid class composition were shown between male and female calves, therefore calves in this study were not separated due to sex. All animals came from northern Västerbotten in Sweden, but from two different herds. All the adult animals (n=14), and a group of seven calves came from the same herd and had been grazing winter pasture in the forest about 30 km south of Skellefteå, whereas the other calves were fed one of two different pelleted feed mixtures *ad libitum* for two months before slaughter; seven calves received a control diet of conventional pellets (CPD) (Renfor Bas, Lantmännen, Holmsund, Sweden) and 10 calves received pellets enriched with linseed cake (LPD) (Table 1). All pellet-fed reindeer came from the same herd and were kept in corrals at the reindeer herder's (Peter Omma, Hemavan, Ubmeje) farm in bigger groups of about 50-200 animals during the feeding period. All animals were slaughtered in early April, according to common procedures at the abattoirs (Grundnäs Kött AB and Arvidsjaur Renslakt AB, Sweden). At slaughter, we recorded dressed carcass weight; carcass conformation (EUROP system, The Swedish Board of Agriculture, 2002) and trim fat were evaluated ocularly according to the EUROP standards. We sampled directly after slaughter (about 45 min *post mortem*) from *M. longissimus thoracis* which was frozen immediately at –20 °C for 6 days and finally stored at –80 °C until analysis.

Feed samples

We collected samples of pelleted feeds and the upper, living parts of lichens (*Cladina arbuscula, Cetraria islandica, Cladina stellaris, Cladina mitis*) from the reindeer grazing area. Dry lichens were stored at –80 °C until analysis.

Lipid analyses

Extraction of lipid from the meat

We performed lipid extraction according to Hara & Radin (1978), with minor modifications described by Pickova *et al.* (1997). Connective tissues and visible fat were removed, the semifrozen samples were minced, and a sub-sample of ca 5 g of muscle tissue was taken for extraction. We homogenised the samples for 3x30 s in 70 ml of HIP (hexane: isopropanol (3:2, v/v) using an Ultra Turrax (T25, Janke & Kunkel, IKA Werke, Germany). 30 ml of a Na_2SO_4 solution (6.67%) was added. The homogenate was centrifuged for 5 min at 4000 rpm (2103 rcf) (Sorvall Super T21, Sorvall Products L.P., Newton, Connecticut, USA) and the upper phase transferred to a clean flask and evaporated. The IMF of the meat was determined from this total extracted lipid, which was then dissolved in 2 ml chloroform. The samples were stored at –80 °C under a normal atmosphere until further analysis.

Thin layer chromatography (TLC) analysis of lipid classes

The total lipids in meat were analysed by TLC to investigate lipid class composition. For TLC six samples of total lipids of each reindeer group were used. Samples were pooled (3x2) into separate tubes for analysis (n=3 for each group) and analysed in duplicates. As a stationary phase, glass plates pre-coated with silica gel TLC plates (20x10 cm; Silicagel 60; 0.20 mm layer, Merck, Darmstadt, Germany) were used. The analysis described by (Olsen & Henderson, 1989) was used, with slight modifications. Prior to use, the plates were pre-developed to full length with hexane:diethyl ether:acetic acid (85:15:1, v/v/v) as the mobile phase, and dried for 5 min at 110 °C. The upper 1 cm of silica gel was removed and the plates were activated for 1 h at 110 °C and stored in a vacuum dessicator until further use.

Samples were diluted to a concentration of 1µg/µl in hexane, and 5 µl of each was applied with a CAMAG TLC Sampler 4 (Camag Switzerland) 2 cm from the base edge of the TLC plates in 2 mm bands with an application speed of 250 nl/sec. Nitrogen was used as spray gas. All samples were applied in duplicate, and the distance between tracks was 10 mm. The lipids were then separated in a Twin Through Chamber 20x20 cm (Camag Switzerland) using 25 ml hexane:diethyl ether:acetic acid (85:15:1, v/v/v) as the mobile phase. Saturation was increased by placing a piece of dry filter paper in the chamber (Camag, Switzerland). Plates were removed from the chambers when they had run for 6.9 cm from the origin, air dried at room temperature, sprayed with a solution of 3% cupric acetate in 8% phosphoric acid and then charred for 20 min at 160 °C.

Quantitative analysis of the separated lipid classes was done by scanning the plates with a CAMAG TLC Scanner 3 (Camag, Switzerland). The scanning was performed at a speed of 20 mm/sec and a data resolution of 100 µm/step, with a slit dimension of 6.00 x 0.45 mm at a wavelength of 350 nm. Identification of the lipid classes was performed by comparison with an external standard (TLC 18-4A, Nu-Chek Prep, Elysian, USA). For data filtering, the mode Savitsky-Golay 7 and manual baseline correction were used.

Extraction of lipid from the feed

The different feed samples were extracted using the method of Folch *et al.* (1957) with minor modifications. Pellets and dry lichens were milled, and a subsample of 2 g wetted in 8 ml water. The samples were then homogenized for 3x30 s in 150 ml of chloroform:methanol (2:1, v/v) using an Ultra Turrax (T25, Janke & Kunkel, IKA Werke, Germany). The samples were transferred to a separatory funnel, and 40 ml of KCl solution (0.8%) added. The lower phase containing the lipids was transferred to a new flask and evaporated, and the lipid content of the pelleted feed and lichens was determined from this total extracted lipid.

Gas chromatography-mass spectrometry (GC-MS) analyses of the neutral_lipid (NL) fraction of the meat

For identification of the unknown substance, a gas chromatograph (CE Instruments, Milano, Italy) connected to a mass spectrometer (Finnigan, Man-

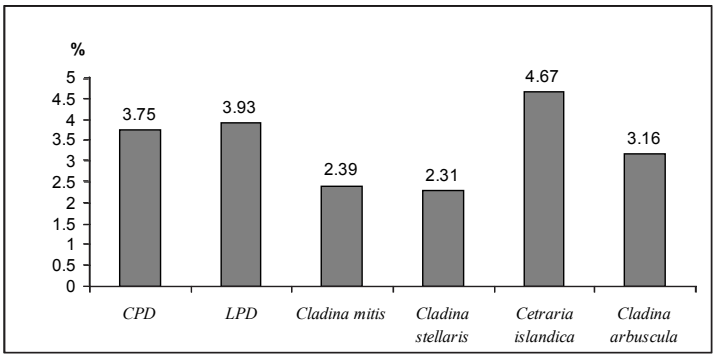

Fig. 1. Total fat content (mean values in %) in pellets and lichen (duplicate samples). Abbreviations: CPD: conventional pellet diet; LPD: linseed pellet diet.

chester, England) was used. The GC was fitted with a BPX 70 column (SGE, Austin, Texas), length 50 m, id 0.22 mm, and film thickness 0.25 µm and programmed to operate at 158 °C, increase to 220 °C at a rate of 2 °C min^{-1}, and then remain constant for additional 13 min. The other GC-conditions were as described in Pickova *et al.* (1997). After extraction, lipids were separated on pre-packed 6 ml solid-phase-extraction (SPE) columns (Isolute SI 500 mg, IST, UK) into NL and polar lipid fractions according to Prieto *et al.* (1992) with slight modifications, and methylated without BF_3 according to Appelqvist (1968). They were then injected onto the GC-MS in the splitless injection mode. Helium was used as carrier gas. The electron energy was 70 eV, the ion source 200 °C, and full-scan mass spectra were recorded (Johnsson & Dutta, 2003).

Statistical analysis

The statistical analyses were carried out with the Statistical Analysis System (SAS Institute, 1997) using the GLM procedure. Treatment including feeding regimen, age and sex was used as fixed factor in the model to compare fat content, carcass conformation parameters and lipid classes.

Results

Fat content of the feed

Of the lichens, *C. mitis* and *C. stellaris* had the lowest fat content, and *Ce. islandica* the highest. The fat levels of the pellets lay between the lowest and highest of the lichens (Fig. 1).

Carcass composition

Female reindeer had a significantly higher mean amount of trim fat compared to males and calves, which did not differ significantly from each other. Calves had a significantly lower mean carcass weight than males or females, which did not differ significantly from each other (Table 2a).

Both groups of pellet fed animals had significantly higher mean amounts of trim fat, and significantly better carcass conformation scores than grazing animals (Table 2b). There was no significant difference in carcass composition between animals fed on the two different pellet diets. The LPD fed animals showed a trend towards higher carcass weight (P=0.062) compared with CPD fed animals, and grazing calves had significantly

Table 2a. Carcass conformation, trim fat content and dressed carcass weight of free ranging reindeer of different age and sex (least-square means and standard errors).

	Males n = 7	Females n = 7	Calves n = 7	P
EUROP carcass conformation[1]	5.0 (0.41)	4.6 (0.41)	4.7 (0.41)	0.756
Trim fat [2]	4.1^{a} (0.33)	5.6^{b} (0.33)	3.9^{a} (0.33)	0.003
Carcass weight (kg)	31.2^{a} (1.21)	32.2^{a} (1.21)	21.0^{b} (1.21)	<0.001

Means with different superscripts within a row differ significantly (P<0.05).

[1]The EUROP system used 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

Where 15 means extremely well developed and 1 emaciated

[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

Where 15 means high and 1 low amounts of subcutaneous fat.

lower carcass weights compared with the pellet fed animals.

IMF and lipid class composition of the meat

In the group of grazing reindeer, females had significantly higher mean levels of IMF than males or calves, which did not differ significantly from each other. Females had significantly higher mean amounts of triacylglycerols (TAG), than calves, and higher levels than males, although this difference was not significant (P=0.061). Calves had significantly lower mean amounts of TAG than both males and females. Females had a significantly lower mean percentage of total phospholipids than males and calves, which did not differ significantly from each other (Table 3a).

There were no significant differences in IMF between calves fed on the two different pellets or grazing calves, but the meat from the grazing calves had a tendency to be leaner compared to the group fed LPD (P=0.0521) There were no significant differences in lipid class composition between meat from the two groups of pellet fed calves, but grazing calves had a significantly higher proportion of both phospholipids and cholesterol, and a significantly lower level of the TAG fraction compared to the pellet-fed calves (Table 3b). We could not detect any free fatty acids in the reindeer meat samples, but found two unknown fractions in the lipid classes.

Table 2b. Carcass conformation, trim fat content and dressed carcass weight of reindeer calves fed different types of pellets compared to free ranging calves (least - square means and standard errors)

	CPD n = 7	LPD n = 10	Grazing n = 7	P
EUROP carcass conformation[1]	5.6[a] (0.16)	5.6[a] (0.16)	4.7[b] (0.19)	0.002
Trim fat[2]	4.7[a] (0.17)	4.8[a] (0.17)	3.9[b] (0.20)	0.003
Carcass weight (kg)	25.4[a] (0.84)	27.8[a] (0.84)	21.0[b] (1.01)	<0.001

Means with different superscripts within a row differ significantly (P<0.05).
Abbreviations: CPD: conventional pellet diet; LPD: linseed pellet diet.
[1,2] see Table 2a.

Table 3a. Fat content and main lipid class composition of free ranging reindeer of different age and sex (least-square means and standard errors)

%	Males n = 7	Females n = 7	Calves n = 7	P
Total fat (IMF)[1]	2.60[a] (0.33)	4.17[b] (0.33)	2.10[a] (0.33)	<0.001
Total phospholipids[2]	39.11[a] (2.93)	28.37[b] (2.93)	46.76[a] (2.93)	0.013
Cholesterol[2]	11.24[ab] (0.93)	8.88[a] (0.93)	12.15[b] (0.93)	0.110
Unknown1[2]	0.43[a] (0.15)	0.55[a] (0.15)	1.44[b] (0.15)	0.005
Unknown2[2]	2.05[a] (0.31)	1.48[a] (0.31)	3.52[b] (0.31)	0.009
TAG[2]	47.17[a] (4.20)	60.87[a] (4.20)	36.14[b] (4.20)	0.017

Means with different superscripts within a row differ significantly (P<0.05).
Abbreviations: IMF: intramuscular fat content; TAG: tri-acylglycerols.

Table 3b. Fat content and main lipid class composition of reindeer calves fed different types of pellets compared to free ranging animals (least-square means and standard errors)

%	CPD n = 7	LPD n = 10	Grazing n = 7	P
Total fat (IMF)[1]	2.49 (0.15)	2.58 (0.11)	2.10 (0.15)	0.129
Total phospholipids[2]	38.96[a] (2.06)	39.44[a] (2.06)	46.76[b] (2.06)	0.064
Cholesterol[2]	9.80[a] (0.43)	10.33[a] (0.43)	12.15[b] (0.43)	0.019
Unknown1[2]	0.36[a] (0.14)	0.12[a] (0.14)	1.44[b] (0.14)	0.001
Unknown2[2]	3.83 (0.24)	3.75 (0.24)	3.52 (0.24)	0.652
TAG[2]	47.07[a] (2.71)	46.43[a] (2.71)	36.14[b] (2.71)	0.050

Means with different superscripts within a row differ significantly (P<0.05).
Abbreviations: CPD: conventional pellet diet; LPD: linseed pellet diet; IMF: intramuscular fat content; TAG: tri-acylglycerols.
[1] % of meat (table 3a and 3b), [2] % of IMF (table 3a and 3b).

GC-MS analyses

Using the GC-MS method described, the unknown substance eluted at 30.79 minutes, (Fig. 2a), and was

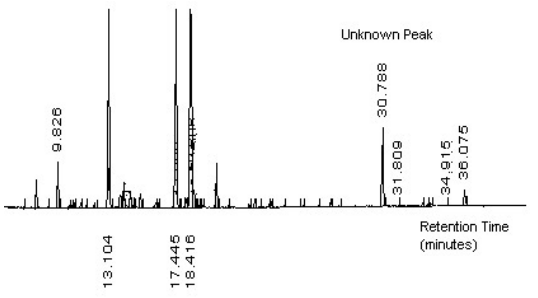

Fig. 2a. Gas chromatogram of neutral lipid fraction of reindeer meat, showing the unknown peak.

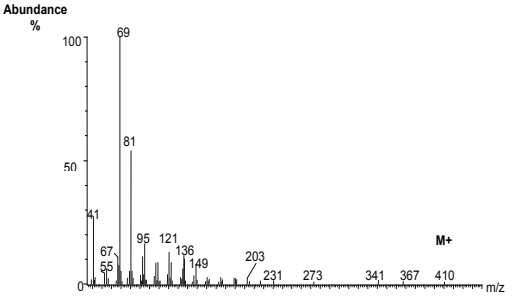

Fig. 2b. GC-MS spectrum of squalene.

present in significantly higher amounts in the grazing calves compared to the other animals. The molecular ion was identified at m/z 410 (M^+, <1%), and the base peak at m/z 69 (tentatively identified as C_5H_9, 100%) (Fig. 2b). Other significant fragments were m/z 367 (tentatively identified as M^+- C_3H_7, <1%), m/z 341 (tentatively identified as M^+- C_5H_9, <5%), m/z 273 (tentatively identified as M^+- $C_{10}H_{17}$, <1%) m/z 231 (tentatively identified as M^+- $C_{13}H_{23}$, <5%) and m/z 203 (tentatively identified as M^+- $C_{15}H_{27}$, <5%) (Fig. 2b). From the elution time and fragmentation pattern, the substance was tentatively identified as squalene, the mass spectrum of which has previously been reported (Christie, 2004).

Squalene

The amounts of squalene in the meat of the CPD-fed and LPD-fed calves were, 1.70% and 1.91% of the NL respectively (Fig. 3). In the grazing animals, squalene was present in amounts representing 1.84%, 0.76% and 3.03% of the total NL in the meat of males, females and grazing calves respectively (Fig. 3). In the present study, squalene was also found in the total lipids of the analysed lichens (0.31%), and in smaller amounts in the total lipids of both types of pellets (0.12%) (Fig. 3).

Discussion

We found interesting differences in lipid class composition between production systems and age and sex and established the presence of squalene in reindeer meat.

Lichens and pellets

The fat content of the *Cladina* lichens was comparable to those found in various species of the same genus in Finland (Nieminen & Heiskari, 1989), al-

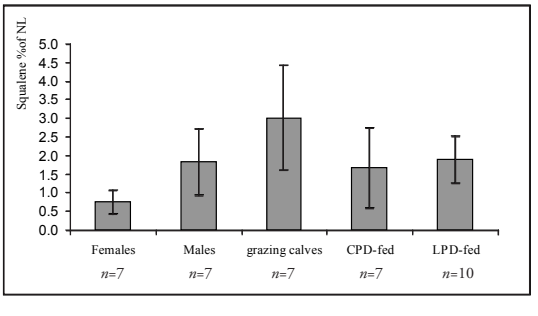

Fig. 3. Squalene content (% of NL and standard deviation) in meat from reindeer fed different types of pellets compared to free ranging animals of different age and sex. Abbreviations: CPD: conventional pellet diet; LPD: linseed pellet diet; NL: neutral lipid fraction.

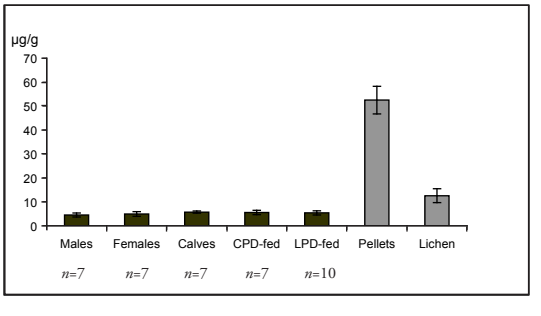

Fig. 4. α-tocopherol content (µg/g) in meat (*M. longissimus thoracis*) from reindeer fed different types of pellets compared to free ranging animals of different age and sex and in pellets and lichen (modified from (Sampels, 2005)) (mean values and standard deviation). Abbreviations: CPD: conventional pellet diet; LPD: linseed pellet diet.

though higher than figures reported in a more recent study in Norway (Storeheier *et al.*, 2002). The fat content of the pellets in general was higher than recorded in the industrial nutrient analyses (Table 1), but the LPD had slightly higher fat content than the CPD, which is in line with industrial analyses.

The squalene found in the pellets probably originated from both wheat (grains 11% and bran 15%), and the 5% palmexpeller used, since squalene is reported to occur in wheat germ (He *et al.*, 2002) and in palm oil (Tan & Kuntom, 1993; Khor & Chieng, 1997). Squalene levels in palm oil are typically 0.4-0.9 mg/g, however, the palmexpeller used contains only low amounts of oil (6%, Sven Hellberg, Lantmännen, pers. comm.), which corresponds to 0.004-0.008% squalene in the total lipids of the pellets. This suggests that the main source of squalene in the pellets was wheat. To our knowledge there is no available data on squalene in lichens. Squalene is a natural triterpene and the precursor for phytosterols (Bosku, 2000; Ostlund, 2002), and therefore is suggested to be present in trace amounts in most green plants containing phytosterols. Significant amounts of plant-derived squalene are detected in olive oil, wheat germ oil, bran oil and yeast (Bosku, 2000), as well as in *Amaranthus* grain and *Echium* plants (He *et al.*, 2002).

Carcass weight and composition

Carcass weights [least-square mean in kg (standard error of the mean)] of pellet-fed calves [25.4 (3.19) and 27.8 (2.13)] for CPD-fed and LPD-fed respectively) were higher than the average weight (22 kg) for all reindeer calves slaughtered in Sweden that year (National Board of Agriculture, 2003). The total IMF content of *M. longissimus dorsi* did not differ between the pellet-fed and grazing calves. However, pellet-fed calves had a higher amount of trim fat than the grazing calves, possibly due to a higher energy intake. The amount of lichens in the winter diet of grazing reindeer is highly variable, and can range from 13-80% of total feed intake (Gaare & Skogland, 1975; Staaland & Sæbø, 1987; Mathiesen *et al.*, 2000; Kumpula, 2001) depending on the availability of lichens on the pasture. In addition to lichens, reindeer also consume dwarf shrubs and graminoids during the winter (Nieminen & Heiskari, 1989; Kumpula, 2001). The metabolisable energy content of lichens is 10.8 MJ/kg DM, and that of dwarf shrubs is around 5-7 MJ/kg DM (Kumpula, 2001), whereas the metabolisable energy content of the pellets was 10 MJ/kg. Considering the high variation in lichen grazing, a lower energy intake can be calculated for the grazing animals as it has been shown that pellet-fed reindeer have a higher dry matter intake and thereby higher energy intake than either lichen-fed or free ranging animals (Storeheier *et al.*, 2003). The results of the present study agree with those of previous studies, in which pellet-fed reindeer had higher carcass weights and trim fat content than the grazing reindeer (Jacobsen *et al.*, 1977; Wiklund, 1996; Wiklund *et al.*, 2001). In ruminants there are differences between species and breeds in the allocation of fat deposition as either marbling or subcutaneous fat (Callow, 1962; Bass *et al.*, 1990). From the present study we conclude that a positive energy balance in reindeer calves leads to an increased subcutaneous fat layer rather than to higher IMF (Tables 2b and 3b). As subcutaneous fat is commonly used as insulation in mammals (Prestrud, 1991), this might be a strategy to protect against cold.

Carcass weight [least-square mean in kg (standard error of the mean)] of the female reindeer [32.2 (4.1)], was close to the Swedish average (33 kg), whereas carcass weights of young males are not included in the statistics (The Swedish Board of Agriculture, 2003).

Our results agree with the fact that male mammals are generally more muscular and less fatty than females (Mersmann, 1990). Studies on other game animals have also shown similar results, with males having higher carcass weights than females (Hoffman *et al.*, 2005). In the present study, female reindeer had higher IMF than males, and this is in agreement with both of the studies mentioned.

It is important for the reindeer's survival and reproduction that they do not loose too much weight and body fat during the winter (Adamczewski *et al.*, 1987). The high trim fat and IMF of the females might be explained by the fact that they need to be in better physical condition, since they must be able to feed their calves, which are born in early spring. Adamczewski *et al.* (1987) showed that poor maternal condition reduces production of viable calves and, based on the observation that muscle weight reached a plateau whereas fat gains continued, and suggested that female reindeer have targets for lev-

els of body fat and protein rather than for total body weight. Therefore, female reindeer would be in better physical condition in early spring not because they consume more feed than the males, but because their metabolic strategy is different (Barboza & Bowyer, 2000). This argument fits well with our data on carcass weights of male and female reindeer (Table 2a). (Ropstad, 2000) showed that optimal criteria for reproduction in wild reindeer cannot be met until females exceed a body weight of 60 kg. Matsuoka *et al.* (1997) found a higher fat content in female goats compared to male goats, and that male and female goats did not differ in slaughter weight, results which are in agreement with our findings.

Another reason for the different trim fat and IMF content between males and females could be different grazing behaviour of reindeer due to sexual segregation, as has been shown for reindeer on the Seward Peninsula (Chetkiewicz *et al.*, 1991), and for other ungulates (Pérez-Barbería & Gordon, 1999; Barboza & Bowyer, 2000). (Barboza & Bowyer, 2000) showed that small female deer (*Cervidae*) often graze on higher quality pasture due to their smaller rumen, resulting in a decreased ability to digest material with high fibre content. Female reindeer keep their antlers during winter, which may give them a higher social status (Karlsson & Constenius, 2000), and we suggest that this may allow them to select grazing grounds more suited to their rumen morphology (*e.g.* easy digestible material).

The lower intramuscular fat content in grazing calves is probably due to the fact that calves are still growing, and therefore not able to deposit fat in the same amounts as adult animals (Adamczewski *et al.*, 1987; Mersmann, 1990). In young animals, energy is mainly used for development of muscle mass, whereas after maturation surplus energy is mainly stored as adipose tissue (Mersmann, 1990). It has also been shown that reindeer calves in their first autumn continue to gain muscle weight, when adult animals have already started to deposit fat (Adamczewski *et al.*, 1987).

Lipid classes

In the present study, the lipid class composition accurately reflected the intramuscular fat content in the different reindeer groups. While phospholipids have functional properties (Sinclair & O'Dea, 1990), TAG serve mainly as an energy reserve and are stored as depot fat, both intramuscular and in adipose tissue (Marmer *et al.*, 1984; Saleh *et al.*, 1999). With an increasing deposition of fat, the percentage of phospholipids usually decreases because they are involved in the cell membrane structure, and are therefore present in relatively stable quantities (Sinclair & O'Dea, 1990; Scollan *et al.*, 2001). Similar results have been demonstrated for cattle and goats (Marmer *et al.*, 1984; Matsuoka *et al.*, 1997). In the current study there was no difference in lipid class composition in the meat from reindeer calves fed on the two different pellets, and the amounts of the different fractions were comparable to those found in an earlier study with pellet-fed reindeer (Sampels *et al.*, 2004). The present study confirms, that reindeer calves deposit fat as an energy resource when their energy intake exceeds their daily need (positive energy balance) (Adamczewski *et al.*, 1987).

In the current study, grazing calves had significantly lower proportions of TAG compared with the adult animals, and significantly higher amounts of phospholipids than females, which agrees well with a lower fat content in the meat as suggested by (Sinclair & O'Dea, 1990). Phospholipids are rich in PUFA (Sinclair & O'Dea, 1990; Scollan *et al.*, 2001), and are important for growth in young animals (Malau-Aduli *et al.*, 1998) *e.g.* for cellular growth (Innis, 1991) and as membrane lipids (Wiseman, 1996). A deficiency of PUFA has been suggested to retard growth in young reindeer (Soppela, 2000), and cholesterol is present in high amounts in plasma (Wiseman, 1996); factors that might explain the significantly higher amounts of phospholipids and cholesterol in grazing reindeer calves compared to female reindeer.

Squalene in the meat

Squalene has been reported to have positive health effects, for example lowering serum cholesterol in hamsters (Khor & Chieng, 1997), chemopreventive effects on colon cancer in rats, and anti tumorigenic activity (Rao *et al.*, 1998).

Levels of squalene were lowest in females, and grazing calves had the highest levels, higher than those found in pellet-fed animals. However, when the amount of squalene is calculated as the total amount of squalene per g meat, the levels are very similar for animals from all treatments (~ 0.02 g/100

g meat). This suggests that the feed is partly responsible for the presence of squalene in the meat, since squalene is present in plant and animal tissue as a key intermediate in the biosynthesis of steroids (He *et al.*, 2002; Ostlund, 2002). There may be a predetermined level for squalene in the muscle, due to its role in the biosynthesis of cholesterol. Levels of squalene detected in reindeer meat are four to ten times higher than those in pork (Slover *et al.*, 1987). Calculated as a percentage of total intramuscular fat, the amounts found in reindeer meat in the present study correspond to 0.5-1% squalene in total fat. These values are relatively high compared with values suggested for common human dietary fats and oils (0.002-0.3% squalene/total fat) (Rao *et al.*, 1998). Further, earlier studies on reindeer meat showed high levels of α-tocopherol (Fig. 4). In the study by (Khor & Chieng, 1997) it was demonstrated that the presence of α-tocopherol enhanced the serum-cholesterol lowering effects of squalene.

Therefore, these results confirm the earlier suggested nutritional value of reindeer meat (Näyhä, 1997; Sampels, 2005).

Conclusion

Reindeer that were fed pellets produced heavier carcasses with better carcass conformation scores compared to grazing reindeer. Increased IMF lead to higher amounts of TAG in the lipids, but differences in fatty acid composition of the two different types of pellets had no influence on tissue lipid class composition.

The discovery of squalene in reindeer meat significantly enhances its proposed nutritional value for humans. Further studies on how dietary squalene is metabolised are recommended in order to provide better control over its levels in reindeer meat.

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Effekt av produktionssystem, ålder och kön på slaktkroppskvalitet och några biokemiska egenskaper hos renkött

Abstract in Swedish / Sammandrag:
Slaktkroppssammansättningen hos renar påverkas av både foderintag, fodersammansättning och djurens ålder och kön. Tidigare har vi visat att renens kön, ålder, mängden intramuskulärt fett (IMF) och putsfett på slaktkroppen påverkar sammansättningen av lipidklasser. Syftet med denna studie var att jämföra lipidklassammansättningen och IMF i relation till slaktkroppens vikt, form och mängden putsfett och att undersöka hur dessa parametrar påverkas av renarnas kön, ålder och olika typer av foder (bete och pellets). Fem grupper renar ingick i studien (totalt 38 djur). Två grupper kalvar utfodrades med två sorters pellets med olika fettsammansättning under två månader före slakt. Den ena gruppen fick normala pellets (CPD) (Renfor Bas) medan den andra gruppen fick pellets som hade en tillsats av linfrökaka (LPD) för att öka mängden n-3 fettsyror i fodret. Dessutom ingick tre grupper betesdjur i studien: vajor, sarvar och kalvar. Utfodring med pellets gav slaktkroppar med bättre klassning, högre slaktvikter och mer putsfett jämfört med slaktkroppar från betande kalvar. Vajorna hade de högsta och betande kalvar de lägsta slaktvikterna, minst putsfett och lägst halt av IMF. Utfodringen med pellets gav ingen signifikant skillnad i IMF mellan betande och utfodrade renkalvar. Vi fann ingen skillnad i lipidklassammansättning mellan de två utfodrade kalvgrupperna, men köttet från de betande kalvarna hade en högre halt av fosfolipider. Vi kunde också identifiera och kvantifiera squalen som en komponent i intramuskulärt fett i renkött.