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Food Chemistry 96 (2006) 524–531
Food Chemistry
www.elsevier.com/locate/foodchem

Nutritional composition of blubber and meat of hooded seal (*Cystophora cristata*) and harp seal (*Phagophilus groenlandicus*) from Greenland

Linn Anne Brunborg [a,*], Kåre Julshamn [a], Ragnar Nortvedt [a,b], Livar Frøyland [a]

[a] *National Institute of Nutrition and Seafood Research (NIFES), P.O. Box 2029 Nordnes, N-5817 Bergen, Norway*
[b] *Section of Applied and Industrial Biology, Department of Biology, University of Bergen Thormøhlensgate 55, N-5020 Bergen, Norway*

Received 19 July 2004; received in revised form 19 July 2004; accepted 7 March 2005

Abstract

Seal blubber and skin are widely used, but the utilisation of blubber and meat for human consumption is limited. The aim of this study was to evaluate the nutritional composition of seal blubber and meat. The fatty acid composition, selected minerals and trace-elements, vitamins, amino acids and proximal composition of blubber and meat from hooded seal (*Cystophora cristata*) and harp seal (*Phagophilus groenlandicus*) from the "West Ice" near Greenland were analysed. The results showed that seal blubber is an excellent source of long- and very long-chain (VLC) $n-3$ polyunsaturated fatty acids (PUFAs), in addition to long- and VLC monounsaturated fatty acids (MUFAs). Eicosapentaenoic acid (EPA) content contributed to a clear separation between blubber and meat from the two species. The blubber of harp seal showed the highest EPA (9.2%), whereas the muscle of harp seal showed the lowest EPA (3%) content. Seal meat is lean with less than 2% total fat, mainly composed of MUFAs, long- and VLC $n-3$ PUFAs. In addition, the meat contains a high amount of proteins with a well-balanced amino acid composition. The trace-element content of seal meat is very high, particularly iron (379 μg/g muscle in hooded seal) and zinc (30 μg/g muscle in harp seal), as also is the vitamin content, especially vitamins A, D_3 and B_{12}. The seals included in this study varied greatly in age and size, which in turn may be the principal reason for the great individual variation observed in nutritional composition. On average, however, consumption of only 40 g seal meat covers the recommended daily intakes of iron and vitamin B_{12} for young women. In conclusion, as long as the products fulfil the amending legislations regarding contaminants, both seal blubber and meat, from the present species, represent high quality food regarding nutrients and bioactive components beneficial for human health.

Keywords: Hooded seal; Harp seal; Seal blubber; Seal meat; Human nutrition; $n-3$ Fatty acids; EPA; DPA; DHA; Minerals; Trace-elements; Essential amino acids

1. Introduction

The main components of seals are carcass (44%), blubber (29%), viscera (18%) and skin (8%) (Shahidi, 1998). The limited consumption of seal meat may partly be due to lack of public knowledge about the nutritional quality. It may also be due to its dark colour, which is related to the high myoglobin and haemoglobin contents of the muscle tissues, and also to flavour deterioration as a consequence of oxidation of unsaturated fatty acids (Shahidi & Synowiecki, 1996). In addition, a negative pressure from animal rights and wild life organisations may also contribute to the restricted use of seal meat. The lipids in seals are mainly stored as subcutaneous fat, also known as blubber. Blubber primarily functions as a body stream-liner, insulator and buoyancy adjuster. In addition, lipids are found in smaller amounts in the

* Corresponding author. Tel.: +47 55 90 51 12; fax: +47 55 90 52 99.
E-mail address: linn.anne.brunborg@nifes.no (L.A. Brunborg).

0308-8146/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2005.03.005

muscle, liver, kidney, heart and other internal organs. The presence of $n-3$ polyunsaturated fatty acids (PUFAs) influences the *post-mortem* storage stability of blubber and meat, due to rapid lipid peroxidation during processing and storage. However, seal blubber oil is more resistant to lipid peroxidation than is cod (*Gadus morhua*) liver oil (Shahidi, Wanasundara, & Brunet, 1994).

Eicosapentaenoic acid (EPA, 20:5$n-3$), docosapentaenoic acid (DPA, 22:5$n-3$) and docosahexaenoic acid (DHA, 22:6$n-3$), long- (i.e. fatty acids with 20–22 carbons in the backbone) and very long-chain (VLC, i.e. fatty acids with 22 or more carbons in the backbone) $n-3$ PUFAs, are present in high amounts in fish oil and seal oil. Long- and VLC $n-3$ PUFAs have been shown to possess many health-promoting effects, including modulating effects on inflammatory mechanisms, and on the immune response in general (Calder, 1998; Empey, Garg, & Fedorack, 1989; Kremer, 2000; Wallace, Keenan, & Finn, 1980). Administration of seal oil to patients with inflammatory bowel disease (IBD) and IBD-associated joint pain, reduces disease activity and joint pain (Arslan et al., 2002; Bjørkkjær et al., 2004). Consumption of seal blubber and meat may therefore contribute with beneficial nutrients. With this in mind, a study, with emphasis on the nutritional value of seal blubber and meat, especially regarding their usage as rich sources of long- and VLC $n-3$ PUFAs, was undertaken.

Long- and VLC $n-3$ PUFAs of seal blubber are located mainly at the end positions (sn-1 or sn-3 positions) of the triacylglycerol (TAG) molecule, whereas they are located mainly in the middle position (sn-2) in fish oils (Brockerhoff, Hoyle, Hwang, & Litchfield, 1967; Wanasundara & Shahidi, 1997; Yoshida et al., 1996). During digestion and throughout the circulation, fatty acids are liberated, primarily from the sn-1 and sn-3 positions of the TAG, by position-specific pancreatic and lipoprotein lipases (Small, 1991). Thus, long- and VLC $n-3$ PUFAs from seal oil may be more readily available for lipolysis than those from fish oils, and may therefore have important and different impacts on both inflammation and on the immune system.

Typical western diets contain excessive amounts of $n-6$ fatty acids, in particular linoleic acid (LA, 18:2$n-6$). LA is the precursor of arachidonic acid (AA, 20:4$n-6$), which in turn is the main precursor of eicosanoids (Gil, 2002). High levels of AA may promote the pathogenesis of many diseases, such as autoimmune and inflammatory diseases (Simopoulos, 2002a, 2002b). Regular intake of seal blubber (oil) and seal meat will provide a diet high in long- and VLC $n-3$ PUFAs and an increased amount of long- and VLC $n-3$ PUFAs may exert suppressive effects on, e.g., autoimmune and inflammatory diseases (Gordon & Ratiff, 1992; Simopoulos, 2002a).

Seal meat is also an excellent source of trace-elements and minerals, particularly iron and zinc, potassium and phosphorus, respectively. Furthermore, it is a good source of vitamins, especially vitamin B_{12}, and generally it has a higher content of B vitamins than do meats from other animals (Shahidi & Synowiecki, 1993). The crude protein content of seal meat (27%) is higher than those of pork (21%), beef (20%), autumn mackerel (*Scomber scombrus*) (19%) and cod (17%) (Botta, Arsenault, Ryan, & Shouse, 1982), and it is a rich source of nutritionally valuable proteins with a well-balanced amino acid composition (Shahidi, 1998). The content of nucleic acids in the meat is low compared to, e.g., beef (Arasu, Field, Kruggel, & Miller, 1981; Synowiecki & Shahidi, 1992).

The aim of this study was to evaluate and compare the positive nutritional composition of seal blubber and meat of two different seal species, namely hooded seal (*Cystophora cristata*) and harp seal (*Phagophilus groenlandicus*), with common foodstuffs. Since seals range high in the food chain, the accumulation of potentially harmful compounds should also be of concern regarding seal blubber and meat for human consumption, but is outside the scope of the present paper.

2. Materials and methods

2.1. Seal samples

Blubber and meat samples from two different seal species, hooded seal and harp seal, were provided by the Institute of Marine Research (IMR), Bergen, Norway. IMR carried out a research cruise in "The West Ice" near Greenland in March/April, 1999. Samples of blubber and muscle were taken by a standardised procedure. Both blubber and meat samples were taken from deep inside the central dorsal region. The weight of all samples was approximately 100 g. All samples were taken from sexually mature females during the breast-feeding period, aged 4–21 years. The mean weight of the hooded seals was 103 kg (range 81–123 kg) and the mean weight of the harp seals was 135 kg (range 110–173 kg).

2.2. Analytical methods

The fatty acid composition, selected trace-elements and minerals, some lipid- and water-soluble vitamins, amino acid content and proximal chemical composition were determined in blubber and/or muscle from the two seal species. The seal samples were kept frozen at −20 °C for six months prior to analysis.

The fatty acid compositions of the total lipids were determined according to Lie and Lambertsen (1991). The fatty acid composition was calculated using an

integrator (Turbochrom Navigator, Version 6.1), connected to the gas–liquid chromatograph and identification ascertained by standard mixtures of methyl-esters (Nu-Chek, Elyian, USA) (Arslan et al., 2002).

Prior to mineral and trace element analyses, the muscle samples were freeze-dried, pulverised and stored in closed bottles prior to analyses. The samples were wet digested in a Milestone microwave laboratory system (Milestone, Sorisole, Italy) (Julshamn, Thorlasius, & Lea, 2000). The concentrations of Na, K, Mg, Ca, Fe and Zn were determined by flame atomic absorption spectrometry on a Perkin–Elmer 3300 AAS instrument (Norwalk, CT) (Julshamn, Maage, & Wallin, 1998; Liaseth, Julshamn, & Espe, 2003). The concentrations of P and Se were determined by electrothermal atomic absorption spectrometry on a Zeeman Atomic Absorption Spectrometer (Perkin–Elmer 4110 ZL, Norwalk, CT) equipped with a THGA graphite furnace and an AS 72 Autosampler (Liaseth et al., 2003). Hollow cathode lamps were used for Mg, Ca, Fe and Zn, whereas Na and K were run in emission mode. Electrode discharge lamps (EDL) were used for P and Se (Liaseth et al., 2003). The concentrations of Cr, Mn, Co and Cu were determined by semi-quantitative ICP-MS (Julshamn, Lundebye Haldorsen, Heggstad, Berntssen, & Boe, 2004).

Total vitamin A was determined by normal phase high-pressure liquid chromatography (HPLC) with an ultraviolet (UV) detector operating at 325 nm, according to a modified method (Noll, 1996).

For the vitamin D_3 analysis, the samples were extracted with 4 ml chloroform by mixing for 45 min, then 1 ml of water was added and the tubes were cooled in a refrigerator (4 °C) for 30 min and centrifuged for 10 min at 400*g*. The chloroform layer was aspired and dried under nitrogen. The residue was suspended in 250 μl of *n*-hexane–ethanol–isopropanol (96 + 2 + 2, v/v) and applied to a normal-phase HPLC system (4.6 × 150 mm Supelcosil, 3 μm, with a 20-mm Supelguard column Supelco, Inc. Bellefonte, PA, USA) with a UV-detector operating at 265 nm modified from Aksnes and Aarskog (1980).

α-Tochopherol was analysed by normal phase HPLC with fluorescence detection (excitation 289 nm, emission 331 nm) according to Lambertsen and Brækkan (1959) with some modifications (Lie, Sandvin, & Waagbø, 1994).

The B-vitamins were analysed using semi-automated microbial assays. Micro organisms (standard concentration, growth medium and incubation of the test organisms, for the analysis of the B-vitamins) were cryo-preserved in Nunc tubes at −80 °C according to Tanguay (1959). Thiamine determination was carried out according to Bell (1974) with some modifications (Mæland, Rønnestad, Fyhn, Berg, & Waagbø, 2000). The growth media for the B-vitamins were as follows: baco thiamine assay medium LV, baco pyridoxine (vitamin B_6) Y-medium, baco folic acid casei medium; all obtained from Difco (St. Louis, USA), vitamin B_{12}-(lactobacillus) assay broth was obtained from Merck (Darmstadt, Germany).

The amino acid composition of the hydrolysate was determined after hydrolysis in 6 M HCl at 110 ± 2°C for 22 h and pre-derivatisation with phenylisothiocycanate (PITC®) using 0.25 mM norleucine as internal standard (Cohen, Meys, & Tarvin, 1990). Amino acids were separated on a Waters Pico Tag® Column (3.9 mm × 15 cm) and detected by UV (Waters 441) at 254 nm. The amino acids were identified by retention time using an amino acid standard (Pierce 20088) to which Taurin (Sigma T-0625) and hydroxy-proline (Sigma H-6002) were added.

Nitrogen in the filtered hydrolysate and crude protein in the minced seal meat were analysed in a nitrogen analyser (PE 2410 Series II, USA) and multiplied by 6.25 for estimating the protein content. Dry matter was determined gravimetrically after drying at (104 ± 1 °C) to constant weight. The total lipid content was determined gravimetrically as the sum of free and bound lipid. Free or loosely bound lipids were extracted with petroleum gasoline and thereafter dried at 103 ± 1 °C. Ash content was determined gravimetrically after ashing for 20 h at 550 ± 5 °C.

2.3. Statistical analysis

Data were analysed using the GraphPad InStat (GraphPad Software Inc, San Diego, USA) statistical software package and Statistica for Windows™ 4.5 (StatSoft Inc, USA, 1993). Throughout the text, values are presented as means ± standard error of the mean (SEM), unless otherwise stated. Student's *t*-test (two sided) was used to compare the two species. If no other significance level is specified, P values $\leqslant 0.05$ were regarded as indicating statistically significant differences.

Principal component analysis (Martens & Næss, 1989) was applied to identify and visualise the overall main trends of the differences and equalities in chemical composition of muscle and blubber between the two seal species. The data matrix was pre-treated by auto scaling, i.e. dividing each data column by its standard deviation, thereby preventing large variables with large absolute variance masking the small variables with small absolute variance.

3. Results and discussion

The total lipid content of seal muscle (1.7 g/100 g) (Table 1) was higher than that of breast filet of chicken (1.1 g/100 g), and lower than those of lean beef filet (4.6 g/100 g), lean pork filet (7.1 g/100 g) and autumn

Table 1
Proximal chemical composition of seal meat (mean ± SEM g/100 g wet weight) from hooded seal and harp seal, $n = 10$

Species	Crude protein	Total lipid	Moisture
Harp seal	26.9 ± 0.2^a	1.8 ± 0.4^a	70.8 ± 0.2^a
Hooded seal	26.6 ± 0.2^a	1.6 ± 0.2^a	70.5 ± 0.2^a

Different superscripts indicate significant differences between species (p-values $\leqslant 0.05$).

mackerel (20.2 g/100 g) (Rimestad et al., 2001b). This suggests that seal muscle is a good source of low fat meat. The amount of crude proteins (wet weight) in seal meat (27 g/100 g) was higher than those in breast filet of chicken (24 g/100 g), lean pork filet (22 g/100 g), lean beef filet (20 g/ 100 g), autumn mackerel (18.5 g/100 g) and cod (17 g/100 g). Based on its crude protein content, seal meat is an excellent source of high protein foodstuffs, suitable for human consumption. The content of moisture in seal meat (71 g/100 g) is similar to the moisture contents found in lean pork filet (76 g/100 g), breast filet of chicken (74 g/100 g), cod (70 g/100 g) and beef (68 g/100 g), but higher than in autumn mackerel (60 g/100 g).

The following presents an overview of the results by principal component analysis (PCA). The spread among the individual seals included in the study was considerable, but the multivariate approach simplified the evaluation of the data. A more in-depth description of the data for the various analytes follows the PCA.

The multivariate computations of the data in Tables 2–4 revealed the following main features: even though the average lipid levels in the meats of the two species were quite similar (Table 1), the hooded seals had generally lower total lipid levels in the muscle than had several

Table 2
Total fatty acids (mean ± SEM %) in blubber and meat from hooded seal and harp seal, $n = 25$. The amount of identified fatty acids ranged from 91% to 98%

Fatty acids	Blubber		Meat	
	Hooded seal	Harp seal	Hooded seal	Harp seal
$\sum$ saturated	15.4 ± 0.4^a	18.0 ± 0.4^b	21.1 ± 0.4^a	21.5 ± 0.6^a
$\sum$20:1	11.6 ± 0.4^a	$5.6 \pm 0.\ 4^b$	12.0 ± 0.6^a	18 ± 1^b
$\sum$22:1	2.0 ± 0.2^a	7.0 ± 0.6^b	5.9 ± 0.4^a	6.0 ± 0.5^a
$\sum$ monoenes	58.9 ± 0.8^a	52 ± 1^b	59 ± 1^a	56 ± 2^a
18:2$n-6$	1.70 ± 0.02^a	2.01 ± 0.04^b	2.30 ± 0.06^a	2.6 ± 0.1^b
20:3$n-6$	n.d.	n.d.	n.d.	n.d.
20:4$n-6$	0.49 ± 0.02^a	0.4 ± 0^a	2.1 ± 0.1^a	1.0 ± 0.1^b
$\sum n-6$	2.50 ± 0.04^a	2.7 ± 0.1^a	4.4 ± 0.2^a	3.7 ± 0.2^b
20:5$n-3$	4.7 ± 0.1^a	9.2 ± 0.2^b	4.4 ± 0.2^a	3.4 ± 0.2^b
22:5$n-3$	2.1 ± 0.1^a	3.5 ± 0.2^b	1.4 ± 0.1^a	2.8 ± 0.2^b
22:6$n-3$	9.5 ± 0.4^a	7.2 ± 0.4^b	5.6 ± 0.4^a	4.9 ± 0.4^a
$\sum n-3$	20.5 ± 0.6^a	26.0 ± 0.6^b	12.4 ± 0.6^a	12.9 ± 0.6^a
$n-3/n-6$	8.3 ± 0.2^a	9.7 ± 0.2^b	2.9 ± 0.2^a	3.7 ± 0.2^b

Different superscripts within tissues indicate significant differences between the species (p-value $\leqslant 0.05$). n.d., not detected.

Table 3
Minerals and trace-elements (mean ± SEM μg/g wet weight) in meat of hooded seal and harp seal, $n = 25$

Element	Meat		
	Hooded seal	Harp seal	p-value
Cr	0.29 ± 0.03	0.33 ± 0.02	0.2728
Mn	0.12 ± 0.01	0.13 ± 0.01	0.4829
Fe	379 ± 20	240 ± 9	<0.0001
Co	0.003 ± 0.001	0.007 ± 0.001	0.0068
Cu	0.89 ± 0.05	1.04 ± 0.03	0.0132
Zn	22 ± 25	30 ± 2	0.0068
Se	0.26 ± 0.01	0.27 ± 0.01	0.4829
Na	600 ± 22	690 ± 38	0.0459
K	3900 ± 80	3700 ± 60	0.0512
Mg	270 ± 6	250 ± 1	0.0019
Ca	43 ± 3	47 ± 3	0.3505
P	2100 ± 56	2100 ± 36	0.999

of the harp seals, showing more fluctuating levels, and the fatty acid composition was also somewhat different between the two species (Figs. 1 and 2, Table 2). Primarily the higher DPA content in the harp seal muscle and the higher EPA, AA and sum of $n-6$ contents in the hooded seal muscle contributed to separation of the species. Secondly, the levels of trace-elements, especially the zinc contents, separated the two species clearly, with zinc located at the upper left part of the plot, and several other minerals in the right part of the plot. This indicated higher zinc levels in harp seals, and higher potassium and magnesium levels in hooded seals. Also, there seems to be great individual variation in zinc and copper levels within the hooded seal group. Thirdly, thiamine (vitamin B_1), vitamin B_6 (pyridoxine) and folate separated the muscle samples of the two species to some extent. Thiamine was located in the lower part of the plot whereas pyridoxine and folate were located in the upper part of the plot (Fig. 2), thus indicating higher thiamine and lower folate and vitamin B_6 in the hooded seals.

The two species were also clearly separated by another PCA model of the distribution of total lipids, fatty acids and vitamin A in both blubber and muscle from the two species (Figs. 3 and 4). This separation was mainly due to higher levels of sum MUFAs in hooded seals and higher sum of PUFAs in harp seals. No overall separation of blubber and muscle composition was found, although several distinct features were observed. The blubber of hooded seals was characterised by an elevated level of MUFAs, whereas the blubber of harp seals showed higher levels of EPA, thus contributing to a clear separation of the species. The levels of vitamin A and total lipids were closely correlated in both blubber and muscle. Vitamin A, however, did not contribute significantly to the separation of the species, even though the average levels of vitamin A in blubber and muscle were seemingly different, indicating great individual variation within the species. The seals included in this study varied greatly in age and size, which, in turn,

Table 4
Lipid- and water-soluble vitamins (mean ± SEM μg/g wet weight) in blubber and/or meat from hooded seal and harp seal, $n = 10$

	Blubber		Meat	
	Hooded seal	Harp seal	Hooded seal	Harp seal
Vitamin A, total	30 ± 8[a]	15 ± 1[a]	0.6 ± 0.3[a]	0.16 ± 0.06[a]
Vitamin D_3	0.16 ± 0.03[a]	0.029 ± 0.003[b]	0.005 ± 0.002[a]	0.006 ± 0.003[a]
Vitamin E (α-tocopherol)	110 ± 13[a]	70 ± 14[b]	3.4 ± 0.3[a]	6 ± 1[a]
Thiamine (B_1)			2.7 ± 0.5[a]	0.54 ± 0.03[b]
Vitamin B_6			2.1 ± 0.2[a]	2.6 ± 0.3[a]
Vitamin B_{12}			0.048 ± 0.004[a]	0.045 ± 0.003[a]
Folic acid			0.027 ± 0.003[a]	0.035 ± 0.002[b]

Different superscripts indicate significant differences between the species for blubber or meat (p-value $\leqslant 0.05$).

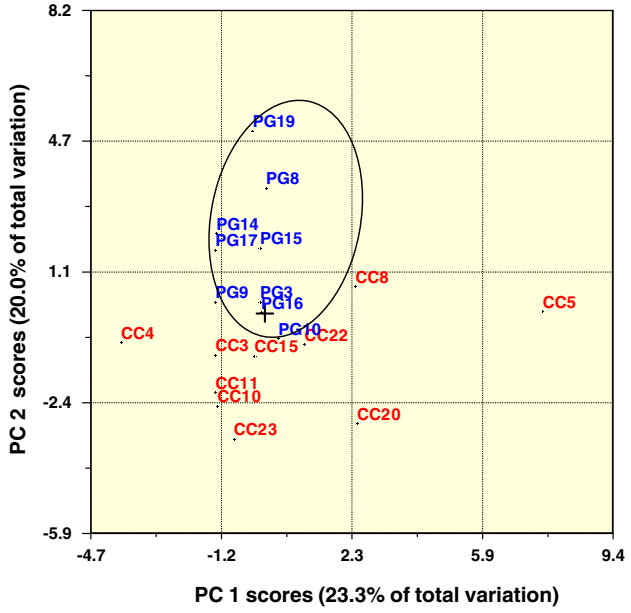

Fig. 1. Scores from a PCA model of fatty acid, B-vitamin, mineral and trace-element composition of muscle of individually coded hooded seals (coded CC) and harp seals (PG). Samples with several missing values are excluded from the model.

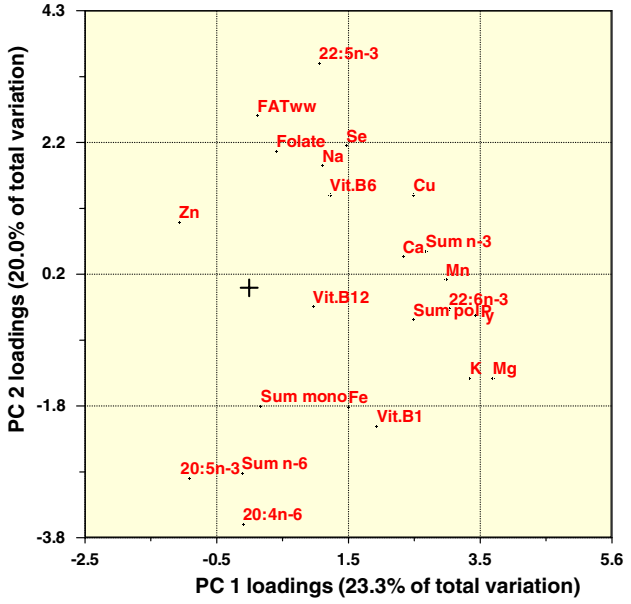

Fig. 2. Loadings from the corresponding PCA model in Fig. 1, showing the correlation between some selected fatty acids, B-vitamins, minerals and trace-elements.

may be the principal reason for the great individual variations observed in several parameters.

The contents of saturated fatty acids, $\sum n-3$, EPA, DPA and the $n-3$ to $n-6$ ratio in blubber were significantly lower in hooded seal than in harp seal (Table 2). The relative contents and compositions of fatty acids of seal lipids were somewhat similar to those of marine fish, but different from those of land-based mammals. The amounts of DPA in seal blubber and meat are relatively high compared to other meat products of both terrestrial and marine origin. DPA is involved in the lipoxygenase (LOX) pathway, and possibly the cyclooxygenase (COX) pathway and is also a strong inhibitor of platelet aggregation (Akiba, Murata, Kitatani, & Sato, 2000), and may therefore ameliorate, e.g., inflammatory disorders. This might represent a good argument for increased human consumption of seal blubber and meat. The diet, both feeding habits and intake, living location and season, as well as physiological changes, such as ageing and maturing, regulate the fatty acid composition of seal blubber and meat, and may therefore explain the variation between different species.

The main differences in mineral and trace-element composition between the two species were found in the content of iron, which was significantly lower in harp seal (240 ± 9 μg/g wet weight, $p < 0.0001$) than in hooded seal (379 ± 20 μg/g wet weight) (Table 3). This may be due to the fact that hooded seals dive deeper than harp seals when they feed, and therefore hooded seals need a higher concentration of oxygen in the blood (i.e. more myoglobin- and haemoglobin-bound iron). The content of iron in seal meat is approximately 400, 60, 35, 35 and 15 times higher than in cod, breast filet of chicken, pork, autumn mackerel and beef, respectively. The calcium level of seal muscle was approximately double the amount found in pork and beef. Besides, seal muscle has approximately six times higher

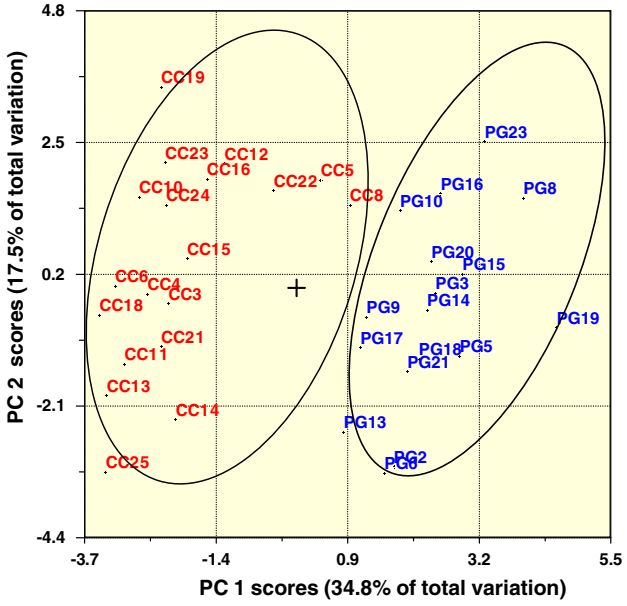

Fig. 3. Scores from a PCA model of the muscle and blubber composition of selected fatty acids, total fat (wet weight) and vitamin A of individually coded hooded seals (coded CC) and harp seals (coded PG). Samples with several missing values are excluded from the model.

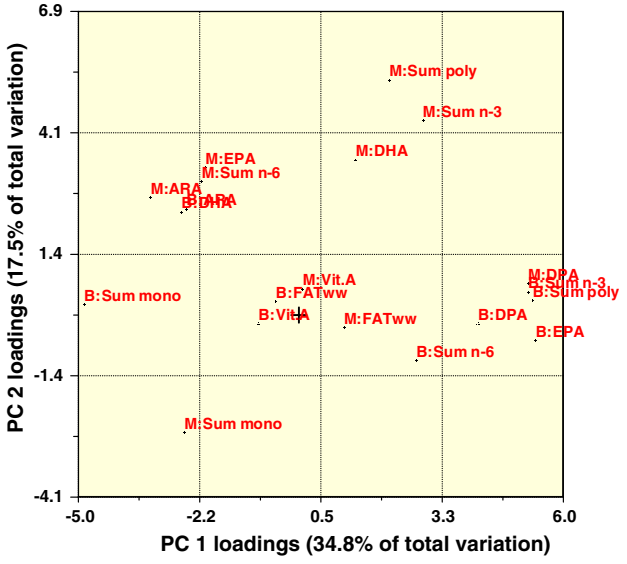

Fig. 4. Loadings from the corresponding PCA model in Fig. 3, showing the correlation between some selected fatty acids, total fat and vitamin A (retinol). M denotes muscle and B denotes blubber.

levels of zinc than does cod. From a nutritional point of view, seal meat is among the best marine food items when it comes to contents of iron, zinc, potassium and phosphorus. The differences in mineral and trace-element composition between hooded seal and harp seal may be ascribed to many factors; the two most important are probably feeding habits and daily feed intake (Kapel, 1995; Nilssen, 1995; Nilssen, Haug, Potelov, Stasenkov, & Timoshenko, 1995; Nilssen, Haug, Potelov, & Timoshenko, 1995; Potelov, Nilssen, Svetochev, & Haug, 1997).

The content of the fat-soluble vitamins D and E were somewhat higher in hooded seal blubber than in harp seal (Table 4), whereas no significant differences were observed for the meat. Selected water-soluble vitamins, namely thiamine, vitamin B_6, vitamin B_{12} and folate, were determined in muscle only. The amounts of the water-soluble vitamins were quite similar in the two seal species, except for thiamine, showing five times higher levels in hooded seal (2.7 ± 0.5 g/g wet weight) than in harp seal (0.54 ± 0.03 μg/g wet weight).

There were no significant differences between the amino acid compositions of muscles from hooded seal and harp seal (Table 5). Limiting amino acids in dietary proteins are typically the sulphur-containing amino acids, tryptophan and/or threonine and lysine. The amounts of tryptophan, threonine and lysine in seal meat were approximately 4.4, 2 and 1.3 times higher, respectively, than in hen egg protein (commonly used as a reference protein with regard to amino acid composition in other food items (Matthews, 1999)).

The nutritional composition of seal meat differs greatly from the nutritional composition of the land-based mammals, among others with higher levels of iron, vitamins A, B_{12}, D_3 and E (Table 6). Seal meat is also superior to some marine foodstuffs (e.g., cod and autumn mackerel), regarding contents of iron, zinc and vitamin A. Consumption of only 40 g seal meat covers the recommended daily intakes (RDI) (Beaton, 1999) of iron and vitamin B_{12} for young women. A 200 g seal steak covers approximately 70% of RDI of phosphorus, 60% of RDI of zinc and 20% of RDI of vitamin D_3. Seal blubber is also rich in MUFA, long- and VLC $n-3$ PUFAs, which possess beneficial health effects (e.g., for coronary heart disease and inflammation), particularly for people with a high $n-6$ to $n-3$ ratio. In addition, the contents of the lipid-soluble vitamins A, D_3 and E are high. Seal muscle is an important source of proteins with a well-balanced amino acid composition; the meat

Table 5
Composition of essential amino acids (mean ± SEM mg/g) in seal meat from hooded seal and harp seal, $n = 10$

	Hooded seal	Harp seal	p-value
Arginine	59.3 ± 0.9	60.5 ± 0.9	0.3583
Histidine	57 ± 2	62 ± 2	0.0940
Isoleucine	39.7 ± 0.6	39.5 ± 0.6	0.8163
Leucine	86 ± 1	84 ± 1	0.1744
Lysine	89 ± 1	89 ± 2	>0.999
Methionine	8.1 ± 0.6	7.7 ± 0.3	0.5584
Phenylalanine	41.7 ± 0.6	41.9 ± 0.6	0.8163
Taurine	3.3 ± 0.6	2.1 ± 0.2	0.0739
Threonine	43.7 ± 0.9	43.8 ± 0.8	0.4739
Tryptophan	43.7 ± 0.9	43.8 ± 0.9	0.9382
Valine	40.2 ± 0.6	40.4 ± 0.6	0.8163

Table 6
Recommended daily intake (RDI) (Beaton, 1999) of selected nutrients for women aged 19–30 in Norway, and % of RDI covered by a 200 g beef of hooded and harp seal muscle, beef, pork, chicken meat, cod and autumn mackerel (Rimestad et al., 2001a)

Nutrient	RDI	Hooded seal[a]	Harp seal[a]	Beef[b]	Pork[c]	Chicken meat[d]	Cod	Autumn mackerel[e]
Ca	800 mg	1	1	1	1	1.5	2	3
P	600 mg	70	70	65	70	73	60	80
K	3.1 g	25	24	25	26	24	29	25
Fe	15 mg	500	320	30	11	7	1	12
Mg	280 mg	19	18	18	12	21	21	20
Zn	7 mg	63	85	114	63	20	14	17
Vitamin A	800 RE[f]	15	4	1	0.5	n.d.	0.5	3
Vitamin D_3	5 μg	20	24	n.d.	n.d.	n.d.	56	500
Vitamin E (α-tocopherol)	8 α-TE[g]	9	15	8	5	3	28	15
Vitamin B_6	1.2 mg	35	43	63	57	85	33	133
Vitamin B_{12}	2.0 μg	480	450	140	40	40	100	1200
Folate	300 μg	2	2	4	2	9	8	0.7

n.d., not detected.
[a] Daily intake covered by 200 g hooded seal and harp seal meat, respectively.
[b] Meat from raw lean beef.
[c] Meat from raw lean pork.
[d] Meat from breast filet of chicken.
[e] Autumn mackerel (July to September, contains more fat compared to winter mackerel).
[f] Retinol equivalents; 1 RE = 1 μg retinol = 6 μg β-carotene.
[g] α-tocopherol equivalents; 1 α-TE equivalent = 1 mg d-α-tocopherol.

is lean and the lipids present are high in MUFAs, long- and VLC $n-3$ PUFAs, in addition to their favourable sn-1 or sn-3 positions of the TAG. Seal meat is also a good source of minerals and trace-elements, especially iron and zinc, compared to other foodstuffs.

In conclusion, seal blubber and meat represent a rich source of long- and VLC $n-3$ PUFAs, in addition to other essential nutrients, such as lipid-soluble vitamins, essential amino acids, minerals and trace-elements.

Acknowledgements

This study was financed by The Norwegian Fishermen Association, The Ministry of Fisheries and the National Institute of Nutrition and Seafood Research (NIFES). The authors are grateful to Vidar Fauskanger, Berit Solli, Idun Kallestad, Vibecke Asphaug and Torill Berg for excellent technical assistance. Special thanks go to Arne Bjørge at the Institute of Marine Research, Bergen, Norway for providing the seal samples along with valuable and important knowledge about these animals and their living habitat. Valuable discussions and constructive comments from Beate Klementsen and Rune Brunborg are highly appreciated.

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