Available online at www.sciencedirect.com
SCIENCE DIRECT
Food Chemistry 100 (2007) 1560–1565
Food Chemistry
www.elsevier.com/locate/foodchem

Chemical composition of meat and blubber of the Cape fur seal (*Arctocephalus pusillus pusillus*)

K.S.C. Koep [a], L.C. Hoffman [a,*], L.M.T. Dicks [b], E. Slinde [c]

[a] *Department of Animal Sciences, University of Stellenbosch, Private Bag X1, P.O. Box 3318, Matieland 7602, South Africa*
[b] *Department of Microbiology, University of Stellenbosch, Private Bag X1, Matieland 7602, South Africa*
[c] *Institute for Marine Research, Bergen, Norway*

Received 13 June 2005; received in revised form 26 October 2005; accepted 29 December 2005

Abstract

Although the Cape fur seal is harvested commercially in southern Africa, no data exist to indicate whether its meat composition is such that it can be consumed by humans. Presently, these animals are harvested mainly for their hides. Little is known about the chemical composition of the meat and blubber and whether it could be processed into food or animal feed. This is the first report on the chemical composition of the *Pectoralis* muscle and fat of seal pups and bulls. The fat content in the muscle of pups was higher (4.2 g/100 g) than recorded in bulls (2.4 g/100 g). The protein content in muscle, on the other hand, was similar (23.2 g/100 g) for animals of both age groups. The blubber of bulls had a higher protein level (26.6 g/100 g) compared to that of pups (14.6 g/100 g), but a lower fat content (67.1 g/100 g vs 77.2 g/100 g). Muscle of bulls contained 33% saturated fatty acids (SFA), 29% monounsaturated fatty acids (MUFA) and 38% polyunsaturated fatty acids (PUFA). Muscle of pups contained 39% SFA, 30% MUFA and 31% PUFA. The toxin content in Cape fur seal blubber was lower than that reported for the blubber of Canadian seals. The organochlorine content in the blubber of Cape fur seals was lower than 13.7 ng/g oil, whereas levels as high as 87.2 ng/g have been reported in Canadian seal oil. The chemical composition of the Cape fur seal is such that it could be classified as a healthy meat source.

Keywords: Cape fur seal; Sustainable harvesting; Protein; Fat; Organochlorine

1. Introduction

The Cape fur seal (*Arctocephalus pusillus pusillus*) bulls and pups are harvested commercially in Namibia on the south-western coast of Africa, mainly for their hides. The remainder of the carcass is normally processed to carcass meal. However, due to strict BSE (*Bovine spongiform encephalopathy*) regulations, the inclusion of animal by-products in animal feed is not allowed. An alternative use for the meat has to be found.

Little research has been conducted on the qualities of marine mammal meat and no information is available on the chemical composition of Cape fur seal meat. Data on the dress out percentages and chemical characteristics of the meat and blubber are also important in commercial production.

The consumption of whale and seal oils benefits the immune system and improves the viscosity and coagulative properties of blood (NAMMCO, 1998). However, very little information exists on the fatty acid composition of the Cape fur seal. A major concern regarding the utilisation of marine mammal tissue is the increasing threat of persistent organic pollutants (POPs) present in the tissue of many seal populations (DeLong, Gilmartin, & Simpson, 1973; Reijnders, 1986). Most of these compounds are found in the high-lipid organs of animals as they are fat-soluble (lipophilic). Since seals have thick blubber layers (Tanabe, Watanabe, Kan, & Tatsukawa, 1988), they are especially vulnerable to POP contamination.

The aim of this study was to study the chemical composition of the meat and blubber of the Cape fur seal

* Corresponding author. Tel.: +27 21 80 84 747; fax: +27 21 80 84 750.
E-mail address: lch@sun.ac.za (L.C. Hoffman).

0308-8146/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2005.12.035

to determine its potential incorporation into human food, animal feed or other products of higher value.

2. Materials and methods

Ten Cape fur seal pups, approximately 8 months old, of both sexes, and 10 Cape fur seal bulls, between 2 and 4 years of age (none being sexually mature), were used. As selective harvesting is not allowed, the pups were not differentiated by gender.

The animals were harvested using standard procedures and then transported to a skinning shed to be eviscerated and the hide removed. At this point, samples of muscle were collected from the *Pectoralis*, and samples of blubber from the ventral side of the carcass. Samples were stored in separate vacuum bags and identified according to the specific animal, vacuum packed, cooled down to room temperature, and frozen at −5 °C.

The moisture and protein contents (g/100 g meat) of all the samples were determined according to the Association of Official Analytical Chemist's Standard Techniques (AOAC, 1997). The accuracy and repeatability of all the techniques are controlled on a bi-monthly basis by means of a National Inter-laboratory scheme (AgriLASA: Agricultural Laboratory Association of South Africa) wherein blind samples are analysed. The moisture content was determined by drying at 105 °C for 24 h. To determine the protein content, dried and defatted meat were ground with a pestle in a mortar to a fine powder. Samples of 0.100 mg were inserted into a foil wrap designed for the Leco protein analyser (Leco Fp-528). The nitrogen content was multiplied by 6.25 to calculate the protein concentration in the sample. An EDTA calibration sample (LECO Corporation, 3000 lake View Avenue, St. Joseph, HI 49085-2396, USA, Part number 502-092, lot number 1038) was analysed with each batch of samples to ensure accuracy and recovery rate. The fat content was determined by homogenising the samples in a blender, followed by chloroform:methanol (2:1) extraction (Lee, Trevino, & Chaiyawat, 1996).

The amino acid composition was determined by using a modification of the HPLC method described by Bidlingmeyer, Cohen, and Tarvin (1984). The meat was defatted by solvent extraction, according to the method of Lee et al. (1996) and then hydrolysed with 6 N HCl in a vacuum-sealed tube for 24 h at 110 °C, centrifuged and dried under vacuum for at least 1.5 h. The pH was adjusted by adding 20 μl ethanol:water:triethylamine (2:2:1) and the sample dried as before. The samples were derivatised by adding 20 μl ethanol:water:triethylamine:phenylisothiocyanate (7:1:1:1) at room temperature (26 °C) for 10 min and then dried under vacuum for at least 3 h. The sample was resuspended in 200 μl Picotag (Waters, Millford, MA, USA), from which 8 μl was then injected into an HPLC (Waters HPLC column, Novapak C18. 60 Å, 4 μm, 3.9 × 150 mm). Separation was by using buffers A (sodium acetate, pH 6.4, 5000 ppm EDTA, triethylamine (1:2000) and 6%, v/v, acetonitrile) and B (60%, v/v, acetonitrile and 5000 ppm EDTA). A 1525 HPLC with a binary gradient delivery, 717 auto-sampler and injector, 1500 column heater, 2487 dual wavelength UV detector were also used in the analysis by Breeze software Z (Waters, Milford, MA, USA). Accuracy and repeatability of this analysis is ensured by inclusion of a control sample of known amino acid composition with the samples prior to hydrolysis.

The samples used for mineral analysis were ashed in an oven at 200 °C, before being dissolved in 3 N HCl and diluted to appropriate concentrations required for mineral analysis by the AOAC method No. 968.08 (AOAC, 1997). Three macro elements (Na, K, and Mg) and two trace elements (Fe and Zn) were determined, using a Varian (spectra AA 250), atomic absorption spectrophotometer equipped with hollow cathode lamps specific to each element and an air-acetylene flame. The instrument setting and conditions used were as described by the manufacturer. Detection of K, Na, Mg, Fe and Zn was at 766.4, 588.9, 330.2, 285.2, 248.3 and 213.9 nm, respectively. Accuracy and repeatability of this analysis is also ensured through the AgriLSA Inter-laboratory scheme.

The fatty acid content was determined by using the method of Tichelaar, Smuts, van Stuiivenberg, Faber, and Benadé (1998). After thawing the meat, the lipids in a 2 g sample were extracted with chloroform/methanol (2:1) and 0.01% (v/v) butylated hydroxytoluene (BHT) as antioxidant. The samples were homogenised for 30 s in a polytron mixer (Kinematica, type PT 10-35, Switzerland) and transmethylated for 2 h at 70 °C with methanol/sulphuric acid (19:1; v/v). After cooling to room temperature, the fatty acid methyl esters (FAME) were extracted with water and hexane. The top hexane phase was transferred to a spotting tube and dried under nitrogen. The FAME were purified by TLC (silica gel 60 plates) and analysed by GLC (Varian Model 3300, equipped with a flame ionisation detector), using a 60 m BPX70 capillary column of 0.25 mm internal diameter (SGE, Australia). The hydrogen gas flow rate was 25 ml/min; and the hydrogen carrier gas rate 2–4 ml/min. Temperature programming was linear at 3 °C/min, with an initial temperature of 150 °C, a final temperature of 220 °C, an injector temperature of 240 °C and a detector temperature of 250 °C. Heptadecanoic acid (C17:0) was used as an internal standard (catalogue number H3500, Sigma–Aldrich Inc. 595 North Harrison Road, Bellefonte, PA 16823-0048, USA). The FAME in the total lipids was identified by comparison of the retention times with those of a standard FAME mixture (SuplecoTM 37 Component FAME Mix, Catalogue Number 18919-1AMP, Lot number, LB-16064. Sigma–Aldrich Inc., North Harrison Road, Bellefonte, PA 16823-0048, USA).

For the determination of POPs, seal oil was collected from a processing plant in Namibia. Additional blubber samples were collected from ten *Phoca vitulina* seals, harvested in Canada. Chlorinated dioxins and furans, and non-*ortho*- and mono-*ortho*-substituted polychlorinated biphenyls (NO- and MO-PCB, respectively) were analysed

according to the method described by MacDonald et al. (1997) and Addison et al. (1999) and analysed by high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS).

The two-sample *T*-test was used on SAS (Statistical Analysis Systems, 1990) to compare the chemical and fatty acid values between bulls and pups.

3. Results and discussion

On dissecting the relevant animals, it was noticed that the meat of the pups was lighter in colour compared to that of the bulls. There was a predominant fat depot around the tail of older animals.

Analysis of the protein content in the blubber of the bulls and the pups, showed a higher concentration (26.6 g/100 g) in that of the bulls, than that of the pups (14.6 g/100 g). The fat content of the blubber was 67.1 and 77.2 g/100 g for the bulls and the pups, respectively. The meat (consisting mostly of the *m. pectoralis*) of the pups contained a higher level of fat (4.2 g/100 g) compared to that of bulls (2.4 g/100 g), but had a very similar protein content (23.2 g/100 g). The protein content in the blubber was not consistent with that of superficial muscle, but rather of connective tissue – on drying, the blubber became rubbery rather than brittle. As connective tissue increases with age of the animal, the protein content in the blubber of the bulls would be higher than that of the pups. As seen from the *P* values in Table 1, all components of the tissues differed ($P < 0.05$), except the protein concentration in the muscle.

There are eight amino acids (isoleucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine) essential for maintaining the nitrogen balance in young adults (Rose, Wixom, Lockhart & Lambert, 1955). In light of recently adjusted estimates of the amino acid requirements for human adults proposed by Pellett and Young (1990), seal meat would be a valuable source of essential amino acids (Table 2), especially leucine and histidine, but contains low levels of cystine. The four major amino acids detected were glutamic acid (3.0 g/100 g meat), alanine (2.1 g/100 g meat), aspartic acid (2.0 g/100 g meat) and glycine (2.0 g/100 g meat). Leucine (1.8 g/100 g meat) is the major essential amino acid in seal meat, followed by lysine (1.5 g/100 g meat).

Mg is the most predominant mineral (634 mg/100 g meat) in seal meat and is approximately 5 times higher than K (174 mg/100 g meat; Table 3). The level of Na (49.9 mg/100 g meat) was also higher compared to that of Fe (4.1 mg/100 g meat) and Zn (2.9 mg/100 g meat). The Fe content at 4.1 mg/100g is much higher than that of pork (1.4 mg/100 g), beef (2.3 mg/100 g) and mutton (1.0 mg/100 g) (Lawrie, 1998).

The standard deviations for the different mineral contents are quite large (Table 3), which might be caused by the fact that body mineral composition is affected by age, feeding regimen, breeding season and geographical differences. In the animals used for this trial, possible slight age differences within the group of bulls sampled, as well as differences in their body conditions, might have contributed to these variations.

As stated by Shahidi, Synowiecki, Amarowicz, and Wanasundra (1994), the deposition of lipids in the seal is found subcutaneous in the form of blubber. This consists mostly of neutral lipids (98.9%), and small quantities of polar lipids. According to Shahidi and Synowiecki (1993), seal meat is comparable to, or better than, other sources

Table 2
Mean values (g/100 g meat sample) of the amino acid profile of the *m. pectoralis* of 10 Cape fur seal bulls

Essential amino acids	Mean ± SD	Non-essential amino acids	Mean ± SD
Histidine	0.7 ± 0.1	Alanine	2.1 ± 0.2
Isoleucine	0.6 ± 0.1	Arginine	1.0 ± 0.1
Leucine	1.8 ± 0.2	Aspartic acid	2.0 ± 0.2
Lysine	1.5 ± 0.2	Glutamic acid	3.0 ± 0.3
Methionine	0.6 ± 0.1	Glycine	2.0 ± 0.3
Cystine	0.2 ± 0.0	Proline	1.1 ± 0.1
Phenylalanine	0.7 ± 0.0	Serine	1.3 ± 0.1
Threonine	1.2 ± 0.1		
Tyrosine	0.5 ± 0.1		
Valine	1.0 ± 0.1		

The table shows data for bulls only, as no samples were analysed for the pups.

Table 3
The mean mineral composition (mg/100 g meat) of the *m. pectoralis* of 10 Cape fur seal bulls

Mineral	Mean ± SD
Iron (Fe)	4.1 ± 0.2
Magnesium (Mg)	634.0 ± 6.0
Potassium (K)	174.0 ± 2.4
Sodium (Na)	49.9 ± 0.5
Zinc (Zn)	2.9 ± 0.2

Table 1
Mean (±SD) and *P*-values indicating differences between the chemical composition (g/100 g sample) of the meat (predominantly the *m.pectoralis*) and blubber of 10 Cape fur seal pups and 10 Cape fur seal bulls

	Meat			Blubber		
	Moisture	Protein	Fat	Moisture	Protein	Fat
Pups	73.0 ± 1.6	23.3 ± 1.6	4.2 ± 1.8	8.0 ± 2.0	14.6 ± 3.0	77.2 ± 1.9
Bulls	74.3 ± 1.6	23.6 ± 1.5	2.4 ± 0.9	6.0 ± 1.6	26.6 ± 4.4	67.1 ± 4.8
P-value	0.0023	0.4825	0.0000	0.0001	0.0000	0.0000

of animal protein in terms of its intramuscular lipids. Furthermore, the lipids in blubber are excellent sources of omega−3 fatty acids (Shahidi et al., 1994). This was substantiated by the results in this trial (see Tables 4 and 5).

Table 4 shows the mean values in mg/100 g of the fatty acids in the *m. pectoralis* and blubber of Cape fur seal bulls, and pups. In muscle, palmitic acid is the most dominant fatty acid, followed by eicosapentanoic (EPA) and then palmiteleidic and oleic acids, in similar concentrations. Table 5 is a representation of the same data from Table 4, but in percentage format. Table 5 also incorporates the P values of the muscle and blubber when compared between the two age groups. Significant differences were recorded in the muscle fatty acid values between bulls and pups. The only fatty acids not significantly different in the muscles are behenic (22:0), oleic (18:1$n-9$), erucic (22:1$n-9$), linoleic (18:2$n-6$), α-linolenic (18:3$n-3$), γ-linolenic (18:3$n-6$), 20:2$n-6$, and DPA (22:5). Significant differences ($P < 0.05$) were also found in the fatty acids of muscle and blubber, although the differences were higher in muscle. Mainly polyunsaturated and monounsaturated acids differed statistically. As the diet between adults (fish) and young (milk) differs, this could be the main contributor to this result. The only fatty acids significantly different ($P < 0.05$) in the blubber of the pups and bulls, were behenic (22:0), 20:3$n-3$ and γ-linolenic (18:3$n-6$) acid. The bulls had the higher concentration of all three, compared to the pups.

Muscle of bulls contained 33% saturated fatty acids (SFA), 29% monounsaturated fatty acids (MUFA) and 38% polyunsaturated fatty acids (PUFA) whilst the muscle of the pups contained 39% SFA, 30% MUFA and 31%, PUFA. These differences could also be attributed to the diet of the young seals, which were all at the stage of being weaned. Compared to bulls, pups have a higher level of docosohexaenoic (DHA) fatty acid. DHA is important for optimal development of the central nervous system and visual performance in humans (Kim & Edsall, 1999).

PUFA, such as the omega−3 fatty acids, have recently become increasingly popular in human diets, due to their

Table 4
Mean values ± SD of the fatty acid composition (mg/100g muscle or blubber) of the *m. pectoralis* and blubber of 10 Cape fur seal bulls and pups

Fatty acid	Bulls		Pups	
	Muscle	Blubber	Muscle	Blubber
SFA				
16:0	194.4 ± 0.6	1326.7 ± 5.6	626.9 ± 1.8	2213.7 ± 5.9
18:0	119.9 ± 0.2	377.9 ± 1.4	214.1 ± 0.5	405.8 ± 0.9
20:0	34.2 ± 0.2	58.1 ± 0.4	25.1 ± 0.1	37.1 ± 0.2
22:0	nd	93.2 ± 1.8	5.6 ± 0.1	57.6 ± 1.0
24:0	40.5 ± 0.6	52.1 ± 0.3	12.7 ± 0.1	51.2 ± 0.1
MUFA				
16:1$n-7$	39.7 ± 0.2	819.5 ± 4.0	164.7 ± 0.7	943.5 ± 2.4
18:1$n-9$	213.0 ± 0.8	813.8 ± 8.7	395.8 ± 4.0	2204.0 ± 14.6
20.1$n-9$	34.2 ± 0.2	239.1 ± 2.0	58.6 ± 0.4	299.8 ± 1.5
22:1$n-9$	29.8 ± 0.1	246.7 ± 2.0	44.8 ± 0.4	148.6 ± 1.0
24:1$n-9$	27.7 ± 0.3	38.6 ± 0.2	19.8 ± 0.1	33.0 ± 0.2
PUFA				
18:2 $n-6$	70.1 ± 0.2	296.1 ± 2.6	232.6 ± 0.8	176.7 ± 0.3
18:3$n-3$	9.2 ± 0.1	60.8 ± 0.1	17.1 ± 0.1	71.2 ± 0.2
18:3$n-6$	18.7 ± 0.2	23.2 ± 0.2	13.0 ± 0.06	17.5 ± 0.1
20:2$n-6$	16.3 ± 0.1	35.2 ± 0.1	14.1 ± 0.1	26.4 ± 0.1
20:3$n-3$	51.5 ± 0.3	96.4 ± 0.7	109.9 ± 0.4	200.9 ± 0.7
20:4$n-6$	22.4 ± 0.3	67.8 ± 0.7	25.3 ± 0.4	8.9 ± 0.1
20:5	68.5 ± 0.4	898.8 ± 4.5	171.3 ± 0.7	811.3 ± 1.4
22:2	nd	28.0 ± 0.1	9.8 ± 0.08	14.60 ± 0.1
22:5	69.3 ± 1.0	573.5 ± 4.3	71.6 ± 1.1	446.6 ± 4.9
22:6	120.0 ± 0.7	187.0 ± 9.2	45.7 ± 2.1	2208.0 ± 4.7
Total				
∑SFA	389.0	1908.0	884.4	2765.4
∑MUFA	344.4	2157.7	683.7	3628.9
∑PUFA	446.0	2266.8	710.4	3982.1
∑TUFA	790.4	4424.5	1394.1	7611.0
DFA	910.3	4802.4	1608.2	8016.8
P:S	1.15	1.19	0.80	1.44
$n-6$	127.5	422.3	75	229.5
$n-3$	60.7	157.2	127	272.1
$n-6$:$n-3$	2.10	2.69	0.59	0.84

SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; TUFA = total unsaturated fatty acids; DFA = desirable fatty acids (C18:0 + TUFA); P:S = PUFA:SFA; nd = not detected.

Table 5
Percentage composition of the fatty acid composition (% of total fatty acids identified) of the *m. pectoralis* and blubber of 10 Cape fur seal bulls and 10 pups

Fatty acid	Bulls		Pups		*P*-value	
	Muscle	Blubber	Muscle	Blubber	Muscle	Blubber
SFA						
16:0	16.9	17.3	24.0	22.0	0.00	0.11
18:0	10.8	5.7	8.4	4.1	0.00	0.81
20:0	2.8	1.1	1.0	0.4	0.05	0.29
22:0	0.4	1.0	0.2	0.5	0.42	0.04
24:0	2.9	0.9	0.5	0.5	0.03	0.22
MUFA						
16:1$n-7$	3.3	9.5	6.1	9.4	0.07	0.63
18:1$n-9$	18.1	8.8	13.7	18.8	0.80	0.35
20.1$n-9$	3.0	2.7	2.0	2.6	0.00	0.19
22:1$n-9$	2.5	3.3	1.7	1.6	0.10	0.22
24:1$n-9$	2.1	0.6	0.8	0.3	0.06	0.09
PUFA						
18:2$n-6$	6.3	4.7	8.9	1.8	0.95	0.44
18:3$n-3$	0.7	1.1	0.7	0.7	0.41	0.06
18:3$n-6$	1.6	1.1	0.5	0.4	0.18	0.42
20:2$n-6$	1.3	0.6	0.5	0.3	0.61	0.90
20:3$n-3$	4.5	1.4	4.5	2.0	0.05	0.01
20:4$n-6$	1.9	1.5	1.0	0.1	0.00	0.13
20:5	5.4	10.4	6.3	8.4	0.00	0.16
22:2	1.4	0.5	0.4	0.2	0.00	0.24
22:5	4.6	6.4	2.2	3.9	0.12	0.26
22:6	9.5	22.2	16.7	22.4	0.00	0.32

apparent health benefits. The ratio of PUFA to SFA (P:S ratio) was higher in the blubber of the pups than in the blubber of bulls (1.44 and 1.15, respectively). However, in the *m. pectoralis*, the bulls had a higher value than the pups (1.15 compared to 0.80). From a human dietary perspective, the aim is to bring the P:S ratio of meat to >0.70, and the $n-6$:$n-3$ ratio to <5.0 (Raes, De Smet, & Demeyer, 2004; Sanudo et al., 2000). The P:S ratio of the muscle and blubber of the bulls and pups was >0.70 (Table 4). Although the $n-6$:$n-3$ ratio was higher in the tissue of the bulls (2.10 and 2.69, respectively), than that of the pups (0.59 and 0.84, respectively), it was still lower than 5.0, thus indicating that the meat and blubber could be classified as being advantageous for human consumption.

Table 6
Organochlorine components of seal oil from the Namibian Cape fur seal and Canadian seal (ng/g oil) (Institute of Marine Research, Bergen, Norway)

Component	Cape fur seal	Canadian seal[a]
PCB#28	0.8	13.4
PCB#52	1.1	14.6
PCB#101	2.5	17.5
PCB#105	1.2	2.0
PCB#118	4.9	23.5
PCB#138	8.3	53.2
PCB#153	13.7	87.2
PCB#156	0.7	2.6
PCB#180	4.2	18.6
ppDDD	13.1	17.3
ppDDT	16.2	23.8
Dieldrin	1.0	1.7
HCB	0.6	61.3
a-HCH	0.1	79.1
b-HCH	8.6	16.5
g-HCH	1.0	5.5
Transnonachlor	18.5	165.5

[a] Unpublished data.

According to Nyman, Koistinen, Fant, Vartiainen, and Helle (2002), the liver:blubber ratio in seals is equal to one, which implies that the PCB and DDT burden is at equilibrium. The Cape fur seal has low levels of toxins in its oil compared with the oil from the Canadian seal (Table 6). This is consistent with results reported by Vetter, Weichbrodt, Scholz, Luckas, and Oelschläger (1999). No organochlorine component of the Cape fur seal was found in larger quantities than 13.7 ng/g oil, whereas the maximum amount for the same PCB was 87.2 ng/g in the Canadian seal. The lowest concentration of an organochlorine component in the oil of the Cape fur seal was 0.8 ng/g (PCB#28), whereas the lowest value for the Canadian seals was 2.0 ng/g (PCB#105). According to Vetter et al. (1999), the reason for such low organochlorine levels in the Namibian Cape fur seal might be due to the fact that the Benguela current dries out the coastline, resulting in a belt of non-arable land, 100–150 km wide. This implies that there is no direct organochlorine input except for rivers, which is also unlikely, since the regional input would remain limited mainly to the Orange River in South Africa.

4. Conclusion

Seal meat can be regarded as an exotic red meat species. The results of this investigation indicate that the seal is an animal whose meat and blubber characteristics make it suitable for use in the human food chain. It can be regarded as an aquatic venison species, which has had no artificial additives in its feed or administered otherwise, and can, thus, be viewed as organic meat. As people are becoming increasingly aware of the origins of any meat they eat, the fact that the seal has had no contaminating human contact whatsoever counts heavily in its favour.

This research has shown that the seal can be regarded as an important contributor toward the mineral, amino acid and polyunsaturated fatty acid requirements of humans. The research findings show that seal meat is lean, with very high protein content, with most of the fat being stored subcutaneously as blubber. This makes it a healthy, low fat alternative to other traditional red meat species, such as beef, mutton and pork. With its low toxin content the oil could be processed into capsules and sold commercially for human consumption, providing another potential alternative use for this animal. As also seen in this investigation, seal blubber has optimum ratios of $n-6{:}n-3$, P:S and high levels of desirable fatty acids. This indicates that the oil produced from this blubber would be a healthy alternative for the consumer.

Countries with concessions to harvest seals such as Namibia, could benefit from the full utilisation of the animal. More research is needed with regard to the processing of the meat, as well as the blubber, into products suitable for human consumption, because harvesting is currently carried out in line with the main interests of the hide and animal feed industries and no regard is presently paid to the cleanliness and hygiene of these operations. However, if harvesting were to become more orientated towards producing meat for the human food industry, there would be a need for a comprehensive design of a processing plant specifically geared towards seal utilisation. Apart from this, commercialisation of seal meat harvesting would have substantial ramifications in terms of job opportunities and increased economic returns and foreign exchange revenues for the countries involved.

References

Addison, R. F., Ikonomou, M. G., & Stobo, W. T. (1999). Polychlorinated dibenzo-p-dioxins and furans and non-*ortho* and mono-*ortho* chlorine substituted polychlorinated biphenyls in grey seals (*Halichoerus grypus*) from Sable Island, Nova Scotia, in 1995. *Marine Environmental Research, 47*, 225–240.

AOAC. (1997). *Official methods of analysis*. (16th ed.). Washington, DC, USA: Association of Official Analytical Chemists Inc.

Bidlingmeyer, B. A., Cohen, S. A., & Tarvin, T. L. (1984). Rapid analysis of amino acids using pre-column derivatisation. *Journal of Chromatography-Biomedical Applications, 336*, 93–104.

DeLong, R. L., Gilmartin, W. G., & Simpson, J. G. (1973). Premature births in Californian seal lions: association with high organochlorine pollutant residue levels. *Science, 181*, 1168–1170.

Kim, H. Y., & Edsall, L. (1999). Lipase-catalysed modification of rice bran oil incorporate capric acid. *Journal of the Agricultural and Food Chemistry, 48*, 4439–4443.

Lawrie, R. A. (1998). In *Lawrie's meat science* (p. 261). Cambridge, England: Woodhead Publishing Limited.

Lee, C. M., Trevino, B., & Chaiyawat, M. (1996). A simple and rapid solvent extraction method for determining total lipids in fish tissue. *Journal of the Association of Official Analytical Chemists International, 79*, 487–492.

MacDonald, D. D., Ikonomou, M. G., Rantalainen, A.-L., Rogers, I. H, Sutherland, D., & Van Oostdam, J. (1997). Contaminants in white sturgeon (*Acipenser transmontanus*) from the Upper Fraser River, British Columbia, Canada. *Environmental Toxicology and Chemistry, 16*, 479–490.

NAMMCO. (1998). *North Atlantic Marine Mammal Commission*, University of Tromso, N-9037 Tromso, Norway.

Nyman, M., Koistinen, J., Fant, M. L., Vartiainen, T., & Helle, E. (2002). Current levels of DDT, PCB and trace elements in the Baltic ringed seals (*Phoca hispida baltica*) and grey seals (*Halichoerus grypus*). *Environmental pollution, 119*, 399–412.

Pellett, P. L., & Young, V. R. (1990). Role of meat as a source of protein and essential amino acids in human protein nutrition. In A. M. Pearson & T. R. Dutson (Eds.), *Meat and health* (p. 329–370). Barking, UK: Elsevier Publishers Ltd.

Raes, K., De Smet, S., & Demeyer, D. (2004). Effect of dietary fatty acids on incorporation of long chain polyunsaturated fatty acids and conjugated linoleic acid in calf, beef and pork meat: a review. *Animal Food Science and Technology, 113*, 199–221.

Reijnders, P. J. H. (1986). Reproductive failure in common seals feeding on fish from polluted coastal waters. *Nature, 324*, 456–457.

Rose, W. C., Wixom, R. L., Lockhart, H. B., & Lambert, G. F. (1955). The amino acid requirement of man. XV. The valine requirement; summary and final observations. *Journal of Biological Chemistry, 217*, 987–995.

SAS. (1990). *SAS/STAT user's guide*. Version 6. (4th ed.). Cary, NC: SAS Institute Inc.

Shahidi, F., & Synowiecki, J. (1993). Nutrient composition of mechanically separated and surimi-like seal meat. *Food Chemistry, 47*, 41.

Shahidi, F., Synowiecki, J., Amarowicz, R., & Wanasundra, U. (1994). Omega−3 fatty acid composition and stability of seal lipids. In C.-T. Ho & T. G. Hartman (Eds.), *Lipids in food flavours (ACS symposium series 558)* (p. 233–243). Washington, DC: American Chemical Society.

Tanabe, S., Watanabe, S., Kan, H., & Tatsukawa, R. (1988). Capacity and mode of PCB metabolism in small cetaceans. *Marine Mammal Science, 4*, 103–124.

Tichelaar, H. Y., Smuts, C. M., van Stuiivenberg, M. E., Faber, M., & Benadé, A. J. S. (1998). The fatty acid composition of rural school children with helminth infections. *Asia Pacific Journal Clinical Nutrition, 7*, 196–197.

Vetter, W., Weichbrodt, M., Scholz, E., Luckas, B., & Oelschläger, H. (1999). Levels of organochlorines (DDFT, PCBs, toxaphene, chlordane, dieldrin, and HCHs) in blubber of South African Fur Seals (*Arctocephalus pusillus pusillus*) from Cape Cross/Namibia. *Marine Pollution Bulletin, 38*, 830–836.