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Healthy Compounds in Meat and Blubber of Whales and Seals

Heilsugóð evni í tvøsti og spiki av hvali og kópi

2013

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SERMITGERÐ
Thesis

TØKNIFRÁGREIÐING
Technical Report

UNDIRVÍSINGARTILFAR
Teaching Material

UPPRIT
Notes

NVDRit 2013:07

Heiti / Title **Healthy Compounds in Meat and Blubber of Whales and Seals**

Heilsugóð evni í tvøsti og spiki av hvali og kópi

Høvundur / Author **Hóraldur Joensen**

Ritslag / Report Type **Tøknifrágreiðing/Technical Report**

NVDRit 2013:07

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Útgevandi / Publisher **Náttúruvísindadeildin, Fróðskaparsetur Føroya**

Bústaður / Address **Nóatún 3, FO 100 Tórshavn, Føroyar (Faroe Islands)**

Posturúm / P.O. box **2109, FO 165 Argir, Føroyar (Faroe Islands)**

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Healthy Compounds in Meat and Blubber of Whales and Seals

Heilsugóð evni í tvøsti og spiki av hvali og kópi

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Abstract

A short synopsis is given of whales and seals occurring in Faroese waters and which of these have been hunted and still are. Some of the important nutrients like fatty acids, macroelements and microelements are briefly outlined and their physiological impacts on the human body described. Moreover, generational and transgenerational effects of malnutrition and rational nourishment are succinctly treated. Furthermore, the importance of whaling in the Faroe Islands is concisely evaluated, new feasible technological decontamination processes stated, a short summing up of Faroese dietary surveys and food composition tables is given and some proposals about nutrient and contaminant databases recommended. Eventually, suggested future studies and conclusions.

Úrtak

Stutt yvirlit er gjørt yvir hval og kóp í havinum kring Føroyar og nevnd eru tey sløg, sum hava verðið og framvegis verða veidd. Nøkur týðningarmikil føðsluevni, so sum fitisýrur, macroelementir, microelementir og árin teirra á mannakroppin eru stutt umtalaði. Ávirkanin av hungri og heilsugóðari føði á ættarlið eftir ættarlið er umrødd. Meting av týðninginum av hvalaveiðu í Føroyum er gjørd, og umtalað er nýggj framkomin reinsingarskipan til evnafrøðiliga dálkað grind og spik. Gjørt er yvirlit yvir kostkanningar og føðslutalvur í Føroyum. Loksins er sett fram uppskot um dálkingar- og føðsludatabasur og framtíðar kanningar. At enda, niðurstøður.

Introduction

The discussion about risks and benefits of fish consumption has been ongoing and especially after edible fish species have been gradually so contaminated the last decades that the health aspects of fish and seafood consumption has been questioned. And in January 2010 the international organisations, Food and Agriculture Organisation (FAO) and World Health Organisation (WHO) organised and held an Expert Consultation on the Risks and Benefits of Fish Consumption at FAO Headquarter, Rome Italy. The purpose was to review data on nutrient and specific chemical contaminant levels in many fish species, as well as latest scientific literature covering the risks and benefits of fish consumption. The result is intended to provide guidance to national food safety. However, marine mammals like whales and seals were not included. Since Faroe Islands together with Greenland and Denmark had the chairmanship of Nordic Council of Ministers in 2010, the Faculty of Science and Technology, University of Faroe Islands applied for and succeeded in getting funds from AG-fish, Nordic Council of Ministers, for a workshop entitled “Risks versus Benefits of Whale and Seal Consumption”. This workshop was held in Copenhagen, Friday 14 January 2011. This paper is a more extensive and detailed version of the presentation held at the Copenhagen workshop.

Whales

In the Faroe Islands whaling is still a part of the traditional sustainable exploitation of the marine resources. Thirteen whale species (cetaceans) migrate through and some of them stay in Faroese waters. These are: blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), sei whale (*Balaenoptera borealis*), minke whale (*Balaenoptera acuturostrata*), humpback whale (*Megaptera novaeangliae*), sperm whale (*Physeter macrocephalus*), northern bottlenose whale (*Hyperoodon ampullatus*), killer whale (*Orcinus orca*), long-finned pilot whale (*Globicephala melas*), white-beaked dolphin (*Lagenorhynchus albirostris*), white-sided dolphin (*Lagenorhynchus acutus*), bottlenose dolphin (*Tursiops truncatus*) and harbour porpoise (*Phocoena phocoena*) (Bloch et al. 2000). Harpoon gunning and industrial exploitation of the big baleen and tooth whales ceased decades ago.

The non-commercially hunted species these days are first and foremost long finned pilot whale and thereupon different sorts of dolphins like Atlantic white-sided dolphin and bottlenose dolphin. A low varying number of northern bottlenose whales are also slaughtered annually. The whales are taken by traditional drive fishery (Joensen 2009).

Seals

Seven seal species (pinnipeds) are observed in waters off the Faroe Islands. These are: hooded seal (*Cystophora cristata*), bearded seal (*Erignathus barbatus*), grey seal (*Halichoerus grypus*), harp seal (*Pagophilus groenlandicus*), ringed seal (*Pusa hispida*), harbour seal (*Phoca vitulina*), Atlantic walrus (*Odobenus rosmarus rosmarus*). The grey seal is the only species which is currently breeding in the Faroe Islands. In former times a breeding stock of harbour seal existed in the Faroes. Due to high hunting pressure the stock collapsed. The last was taken in 1845. Since then only migrating harbour seals are seen in Faroese waters (Bloch et al. 2000). Regular and traditional hunting of seals does not occur anymore in the Faroe Islands.

Fatty acids in blubber of marine mammals

Fatty acid composition of a large number of seal- and whale-blubber samples have been measured lately in Canadian Arctic. The marine mammals were 80 bearded seals (*Erignathus barbatus*), 33 harbor seals (*Phoca vitulina*), 239 harp seals (*Pagophilus groenlandicus*), 32 hooded seals (*Cystophora cristata*), 281 ringed seals (*Phoca hispida*), 53 walruses (*Odobenus rosmarus rosmarus*), 105 beluga whales (*Delphinapterus leucas*), and 20 narwhales (*Monodon monoceros*). Except for narwhale the blubber of the other species was fairly rich in the healthy long-chained highly unsaturated fatty acids, LC-HUFA (Thiemann GW and Iverson SJ, 2008). Similarly, analysis of white whale (*Delphinapterus leucas*) shows that its blubber is rich in the healthy long-chained monounsaturated fatty acids, LC-MUFA, and long-chained polyunsaturated fatty acids, LC-PUFA (Dahl et al. 2000).

Stratification of FA in whale blubber

The relative stratification index of fatty acids in blubber columns of longfinned pilot whale, Atlantic white-sided dolphin, bottlenose dolphin, and Northern bottlenose whale caught in the Faroe Islands shows that the short-chained saturated fatty acids, SC-SAFA, short-chained monounsaturated fatty acids, SC-MUFA, and short-chained polyunsaturated fatty acids SC-PUFA are concentrated mainly in the outer layer while the content of long-chained saturated fatty acids LC-SAFA, LC-MUFA and LC-PUFA is higher in the inner layer (Grahl-Nielsen, Joensen, unpublished data). A similar distribution of fatty acids is found in minke whale blubber (Olsen and Grahl-Nielsen 2003).

Seal meat and blubber

A study evaluating the nutritional composition of blubber and meat of hooded seal (*Cystophora cristata*) and harp seal (*Phagophilus groenlandicus*) from Greenland showed that seal blubber is an excellent source of LC-HUFA like eicosapentaenoic acid, EPA, and docosahexaenoic acids, DHA. Seal meat is rich in minerals and proteins with a well-balanced amino acid composition. The content of trace-elements is high, particularly iron (379 µg/g) and zinc (30 µg/g). The vitamin content is also high, especially vitamin A, D3 and B12 (Brunborg et al. 2006). The fatty acid composition of seal (grey seal (*Halichoerus grupus*) and harbour seal (*Phoca vitulina* L.) blubber is significantly different from the animal's diet, probably due to the species specific inherit metabolism (Grahl-Nielsen and Mjaavatten 1991).

Nutrients and POPs South African seal

Chemical analysis of Cape fur seal meat and blubber shows that seal in Southern Africa has a very low burden of persistent organic pollutants (POPs) and the contents of minerals, amino acids and polyunsaturated fatty acids meets well the nutritional requirements of humans (Koep et al. 2007).

B vitamins in whales and seals

A study of traditional foods, including seals and whales, of Canadian Arctic Indigenous Peoples showed so high levels of folate, pyridoxine, niacin and riboflavin that these conventional fares have potential to contribute significantly to the vitamin requirements of these boreal peoples (Hidiroglou et al. 2008).

PUFA from marine mammals is superior

A comparison of marine mammal fat and fish intake showed that fat of seals and whales is more important than fish for red blood cell ω -3 LC-PUFA levels among the Nunavik Inuit, even if daily intake of fish is higher than marine mammal meat and fat (Lucas et al. 2010).

Vitamin A, D, E in whales and seals

Sea mammals fats (beluga, narwhale, seal, walrus) have been found to be not only good but excellent sources of vitamins A, D and E, therefore seals, whales and other traditional food resources rich in fat-soluble nutrients are recommended to protect vitamin nutrition in indigenous boreal populations (Kuhnlein HV et al. 2006).

PUFA distribution on TAG of seal and fish oil – absorption difference

The positional distribution of LC-PUFA like EPA, DPA (docosapentaenoic acid), and DHA in the TAG (triacylglycerol) molecules is different in seal blubber oil and in fish oil. Stereospecific analysis of seal blubber oil has revealed that EPA, DPA, and DHA occurred mainly in the sn-1 and sn-3 positions of the TAG molecules. The same analysis of menhaden oil showed that DPA and DHA occurred mainly in sn-2 position, and EPA was equally distributed in the sn-2 and sn-3 position and only sparsely in the sn-1 position (Wanasundara and Shahidi 1997).

Since fatty acids in the sn-1 and sn-3 position on the TAG are liberated by regio-specific enzymes like pancreatic lipase, and fatty acids attached to the sn-2 position of the TAG are supposed to be absorbed and distributed in the body in a less efficient way, the EPA, DPA, and DHA in seal blubber oil might be more effectively absorbed in the body than those in fish oil (menhaden oil) (Wanasundara and Shahidi 1997).

LC-HUFA accretion in serum PL

Daily consumption of 20 g of encapsulated seal oil resulted in a decrease of the ω -6/ ω -3 ratio and the coagulant inhibitor, protein C, and an increase of EPA, DHA, and DPA, EPA/AA, (AA: arachidonic acid) DHA/AA and NEFA (non-esterified fatty acids) in serum phospholipids (Conquer et al. 1999).

ω -3 and ω -6 FA and physiological impacts

Omega-3 and omega-6 fatty acids (FA) can be altered metabolically to eicosanoids, a class of bioactive molecules including leukotrienes, prostaglandins, and thromboxanes. Eicosanoids derived from omega-3 fatty acids are mainly anti-inflammatory and inhibit platelet aggregation whereas those biosynthesized from omega-6 fatty acids are generally pro-inflammatory and pro-aggregatory. Dietary intake of long-chained highly unsaturated fatty acids, LC-HUFA are found to be inversely related to inflammatory markers such as C-reactive protein, IL-6, E-selectin, soluble intercellular cell-adhesion molecule 1, ICAM-1, soluble vascular cell adhesion molecule 1, VCAM-1, and soluble tumor necrosis factor-alpha receptors. EPA and DHA are also shown to have beneficial influence on ventricular arrhythmias, thrombosis, triglyceride, apolipoprotein B, high-density lipo-protein, adhesion molecule expression in plaque, platelet-derived growth factor, nitric oxide-induced endothelial relaxation and blood pressure reduction (DeFillippis et al. 2005 and references therein). Furthermore, LC-HUFA lowers the level of atherosclerosis,

has antiarrhythmic effects, reduces incidence of congestive heart failure, increase hepatic fatty acid beta-oxidation, suppresses the level of interleukin-B, and increases the level of adiponectin, which reduces inflammation and improves insulin resistivity, reduces heart rate and left ventricular hypertrophy (Lavie et al. 2009 and references therein). A large body of evidence show that intake of EPA or a combination of EPA and DHA is an efficacious adjunctive therapy for several psychiatric disorders, including mood disorders, schizophrenia, and ADHD (Freeman et al. 2006). Moreover, EPA and DHA supplementation delays cognitive decline in patients with Alzheimer's disease (Freund-Levi et al. 2006). There is a growing body of facts indicating that functional deficiencies or imbalances of omega-3 and omega-6 HUFA may play a role in dyslexia, dyspraxia, autism and ADHD (Cyhlarova et al. 2007 and references therein).

w-3 and cancer

Omega-3 FA have been shown to have anti-carcinogenic effects while saturated FA and omega-6 FA may promote cancer development (Prener et al. 1996).

ω -6/ ω -3 ratio increment and consequences

The omega-3 polyunsaturated fatty acids are primarily present in fish, shellfish and marine mammals and are limited in land animals and plants. The current western diet is low in omega-3 LC-HUFA, which has resulted in a change of the ratio of omega-6 to omega-3 intakes from 2 to more than 20 within a century. The negative consequences of this twisted omega-6/omega-3 ratio is increased thrombogenesis, lowered immune response, increased inflammation and decreased neuronal membrane fluidity, function and therewith deteriorated neurotransmission and signalling (Hooijmans and Kiliaan 2008 and references therein).

Marine mammal oil and pain

In a randomized double blind trial whale and seal oil were administered duodenally to patients with inflammatory bowel disease (IBD) and joint pain. The result was a significant reduction of joint pain, back pain and the indexes of IBD-disease activity for both whale and seal oil. Both of the marine oils improved quality of life (Bjørkkjær et al. 2009, Brunborg et al. 2008).

LC-HUFA and mental health

PUFAs are important structural constituents of the central nervous system, and their functional role in learning and memory has been well documented. Mother milk, a good DHA source, compared to formula had a better effect on verbal skill, performance skill, and overall IQ of the participating infants; the difference was 8% to 9 %. During the pregnancy the maternal plasma phospholipid DHA status decreased by some 40 % due to selective mobilisation of DHA to development of brain, retina, eye and heart of the fetus. (Shahidi 2004, Shahidi and Finley 2001).

LC-HUFA and neurons

In a neuroregenerative experiment ω -3 LC- HUFA, especially DHA, had a marked neurite-promoting effect in neurones not only in immature neurones but also in neurons from adult and aged animals (Robson et al. 2010).

LC-HUFA and gene expression

In a nutrigenomic experiment with high-density microarrays used to reveal gene-expression changes in response to different PUFA-enriched diets in rats several genes were up-regulated and others downregulated. The products of the up-regulated genes play major roles in synaptic plasticity, learning (Kitajka et al. 2004 and references therein) and energy/lipid metabolism (Deckelbaum et al. 2006).

The down-regulated genes code for a long list of inflammatory proteins (Deckelbaum et al. 2006). The favourable biological effects of especially EPA and DHA include compositional changes of cell membranes and membrane function, activation or suppressing of signaling molecules, direct interaction with DNA and transcription factors, influence on enzyme activities, influence on the trafficking between vesicular endoplasmatic reticulum and Golgi apparatus, potential scavenging of reactive oxygen species and thereby protection against neuredegeneration, and finally eicosanoids, which are LC-HUFA metbolites (Deckelbaum et al. 2006 and references therein).

LC-HUFA, antioxidants and neuroprotection

Intake of EPA and DHA showed increased antioxidant gene expression, higher glutathione peroxidase (GPx) activity, and thereby protection against excessive reactive oxygen species (ROS) (Kaur et al. 2008 and references therein). It is established that DHA reduces cell-associated MeHg and prooxidant response from MeHg in cerebellar astrocytes and neurons and therefore has the potential to offer neuroprotection from MeHg (Kaur et al. 2008)

Selenium in traditional Greenlandic food

People in Greenland have always had a high intake of selenium through the traditional food of marine origin. Selenium blood levels were significantly correlated with LC-HUFA. The main Se-sources were whale skin, sea birds, seal meat and organs, and fish. Since a rapid westernization of dietary traditions is taking place in Greeland these days the current copious selenium intake is suspected to diminish to an insufficient level in the near future (Hansen et al. 2004).

Selenium health benefit value, Se-HBV

A comprehensive Se-index called Se- health benefit value, Se-HBV, has been created in order to integrate Se-specific nutritional benefits in relation to potential mercury exposure risks.

$$\text{Se-HBV} = (\text{Se:Hg molar ratio} \times \text{total Se}) - (\text{Hg:Se molar ratio} \times \text{total Hg})$$

Marine food, which is methyl-Hg-polluted but rich in Se has a high positive Se-HBV. The toxic effects of methyl-Hg polluted diets rich in Se are therefore significantly diminished rather than exacerbated (Raymond and Ralston 2009). Avoiding LC-HUFA and Se may be hazardous for healthy prenatal neurodevelopment. “Children of mothers who avoided fish consumption during pregnancy showed developmental impairments 60 times greater than the worst case impairments associated with the highest pilot whale consumption in the Faroes “ (Raymond and Ralston 2009 and references therein).

Se-compounds counteract methyl-mercury

Selenium compounds in animal tissues are Se-cysteine, Se-methionine, selenotrisulfides of cystine, selenate, selenite, and several selenoproteins. Some of the more significant mammalian selenoproteins are glutathione peroxidases (GPx, antioxidant enzymes), iodothyronine deiodinases, selenoprotein P, selenoprotein W, selenophosphatase, mitochondrial capsule selenoprotein, prostate epithelial selenoprotein, DNA-bound spermatid selenoprotein and 18kDa selenoprotein. Several studies have revealed that Se protects animals against toxicity of Hg, Cd, Pb, Ag and neurotoxicity of Hg, Cd, Pb and V (Navarro-Alarcon and Cabrera-Vique 2008 and references therein). The Recommended Dietary Allowance (RDA) and Tolerable Upper Intake Level (UL) for Se for adult is 55µg/day and 400 µg/day, respectively. Intake of selenium up-regulates the expression of several genes. The high concentrations of Se compounds in the liver counteract the toxicity of methyl mercury by demethylation and accumulation as mercuric selenide, HgSe, in the lysosomal fraction of hepatocytes (Ikemoto et al. 2004). The absorption mechanism could be a receptor-mediated endocytosis (Renaud et al. 1989). Mercury is also concentrated in the kidney (Endo et al. 2003). The subsequent excretion of HgSe into the faeces goes via the bile duct (Renaud et al. 1989).

Approximately 95% of the absorbed mercury is excreted in the feces and less than 0.05% in the urine (Endo et al. 2003). Human studies (Suzuki et al. 1991 and references therein) show biological excretion half times, of tracer dose of MeHg administered, varying between 52 days and 98 days. The average biological half time is longer in males (79 days) than females (71 days). More severe MeHg poisoning exhibited biological half times in the range of 35 days to 289 days (Suzuki et al. 1991 and references therein). The half times vary between tissues (Curtis 2001 and references therein). Animal studies (Suzuki et al. 1991 and references therein) suggest strongly that the individual differences are genetically based. An adult Canadian with an average number of 8 dental amalgams is estimated to absorb 30 to 40 percent of the total mercury exposure of 5 to 6 mikrogram per day (Curtis 2001 and references therein). Selenium deficiency causes a type of osteoarthritis resulting in enlarged joints, shortened finger, toes, and dwarfism (Navarro-Alarcon and Cabrera-Vique 2008 and references therein).

Whale meat rich in Se

Whale meat is a good Se resource. The concentration of Se in raw fresh cod fillet and raw fresh pilot whale meat is 28 µg/100g and 185 µg/100g, respectively (Poulsen 1995). When compared with other food products such as different fish and fish products, terrestrial meat (chicken, lamb, beef, pork) and meat products, bread cereals and grains, milk cheese and egg, fruit and vegetables the raw pilot meat excels by its extraordinarily high Se concentration (Poulsen 1995).

Transgenerational effects of malnutrition

Animal studies have revealed transgenerational effects of maternal malnutrition during gestation in F0 on increased obesity in adults, glucose intolerance, and altered cardiovascular function in the F1 and F2 generations (Painter et al. 2008 and references therein). Other studies the last two decades have showed that suboptimal nutrition in pregnancy can lead to increased risk of diabetes, hypertension and atherosclerosis developing in the offspring, and that these risk can be heritable (Li CCY et al. 2010 and references therein). Moreover, lifestyle-related and adult-onset diseases such as cardiovascular disorders, asthma and schizophrenia are rooted in gestation, lactation and early nutrition

(Junien 2006 and references therein). Similarly, a study of the transgenerational effects of prenatal exposure to the Dutch winter famine 1944/45 showed that increased neonatal obesity and poor health late in life was not limited to the F1 generation, but continues in the F2 generation (Painter et al. 2008, Matthews and Phillips 2010).

Diet induced transgenerational effects and epigenetics

The topical subject of transgenerational effects of malnutrition during gestation is particularly relevant to rural populations shifting from traditional to western diets. A detailed analysis of the dietary change may elucidate the molecular mechanisms behind the epidemic of diabetes, obesity and cardiovascular diseases (Painter et al. 2008). A potential explanation for the modern life-style induced metabolic syndrome could be a nutrient-based effect mediated by an epigenetically changed gene expressions (Li et al. 2010). These issues will be of paramount importance for the coastal populations in the Northern countries, because part of our natural food resource, the marine mammals, is currently so contaminated that we have to substitute some of our traditional food with foreign and in many cases nutritionally inferior victuals. High quality healthy food is absolutely essential for genetically predisposed people, like GSD3a patients. GSD3a, Glycogen Storage Disease 3a, affects liver and muscles, and is an autosomal recessive disorder in which deficiency of glycogen debranching enzyme activity leads to accumulation of abnormal glycogen with short outer branch chains. Due to the traditional Faroese protein-rich food regime people suffering from GSD 3a live longer and better in the Faroe Islands than in any other country worldwide (Weinstein and Minarich 2011). As a consequence, the healthy Faroese protein-rich fare is now being introduced as a remedy for GSD 3a in USA and other countries instead of the formerly recommended carbohydrates (Weinstein and Minarich 2011). Moreover, several young people from the Faroe Islands suffering from carnitine transporter defect (CTD) have already passed away, probably due to replacement of the carnitine rich traditional food with foreign protein poor fares.

Importance of whaling in the Faroe Islands

The average number of annually slaughtered pilot whales from 1900 to 1999, was 956 individuals. This is approximately 500 tonnes of meat and blubber, and corresponds to roughly 30 % of the total meat production (Wikipedia and references therein). Faroe Islands is an expensive country with the highest rate of taxation in the world. Eight % of the Faroese population has a so low equivalent income that it is characterized as a Risk of Poverty remuneration, according to EU standards. Moreover, 72% has a yearly equivalent income between 195 and 205 thousand Dkr (www.hagstova.fo). Due to these low earnings, pilot whaling is of importance generally, and especially so for the rural population, whose existence is extensively based on a subsistence economy or barter economy rather than monetary economy.

Decontamination of meat and blubber

The technology necessary to remove pollutants from blubber and meat is developed. The development of the pH-shift-filtration method (Nolsøe et al. 2011) has partly taken place in the Faroe Islands. The meat could be grinded in water, the proteins processed, purified and precipitated by the pH shift procedure followed by pressing and further production of sealstick, whalestick or grindstick, something similar to crabstick. The triglycerides in the blubber could be cold extracted without degradation and gently purified in a short path vacuum distillation plant. Subsequently, the oil could be emulsified in a fish gelatine matrix, as protection against oxidative degradation, and thereupon produced and formed into decontaminated healthy artificial blubber of natural appearance.

Faroese Dietary Survey & Food Composition Tables

No public nutrient and contaminant data-base exists in the Faroe Islands. Only three dietary survey (Gudjonson 1937, Vestergaard and Zachariassen 1987, Veyhe 2006) have been conducted ever in this country. As of print matters, a leaflet on nutrients and contaminants in cod (Gregersen and Joensen 2004) and a report on fatty acids in Faroese lamb meat have been published (Jónsdóttir et al. 2001). Additionally, some results from Faroese, Icelandic, Danish, English, Greenlandic and Swedish food analyses have been compiled in a booklet entitled “Faroese Food Composition Tables” (Poulsen 1995, www.hfs.fo). Finally, since the Faroe Islands is a member of the “Nordic information- and communication network regarding safety of seafood products and utilization of resources from the sea” (www.seafoodnet.info), some Faroese information on food components and pollutants is to be found on this network’s homepage.

Regarding contaminants, several reports are on the homepage of Food, Environmental & Veterinary Agency, in Faroe Islands (www.hfs.fo (ritgerðir), www.us.fo).

Recommendations (FAO/WHO 2010 inspired)

- Establish databases on specific nutrients and contaminants in marine mammals consumed in the North Atlantic.
- Develop and evaluate risk management and communication strategies that both minimize risks and maximize benefits from consuming marine mammals.

Future studies of raw and cooked food of marine mammals

- Measure protein, fat, lipid-classis, fatty acids, vitamins, macroelements, microelements and other compounds of interest like carnitin and taurine in different species seasonally.
- Study bioactive peptides in raw and fresh, light to heavy fermented and dry whale and seal meet seasonally.
- Reveal food-health relations in children, youth, adults and the elderly consuming traditional food prepared from marine mammals

Conclusions(FAO/WHO 2010 inspired)

- Consumption of food prepared from marine mammals provides energy, proteins, and a range of essential nutrients.
- Intake of food products from marine mammals is part of the cultural traditions of several boreal peoples and in some populations it is a major source of food and essential nutrients.
- Among the general adult boreal population LC-HUFA and micronutrients from marine mammals increases physical and mental health.

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