3 Nutritional Aspects of Fish Compared with Other Protein Sources

3.1 Introduction

This chapter presents an overview of the consumption rates and nutritional benefits of eating fish. While its specific contributions to the nutritional quality of the diet depend upon the amount of fish (versus other foods) and species (fatty versus lean) consumed, it is most valued as a "protein food". The Biological Value and Protein Efficiency Ratio, indices of the amino acid profile and ability to support growth, are higher for fish than for beef, pork, chicken and milk proteins. In addition, the types and proportions of dietary fats are generally more "heart healthy" than the fats found in other protein foods. Approximately 50% of the fatty acids in lean fish (e.g., walleye and yellow perch) and 25% in fattier fish (e.g., channel catfish and rainbow trout) are polyunsaturated fatty acids. The amount of saturated fatty acids, associated with increased risk of heart disease, tends to be relatively constant across fish species, at about 25% (Sabry, 1990). In contrast, the polyunsaturated and saturated fatty acids in beef are 4-10% and 40-45%, respectively, of the total fatty acids present. Fish is also valued as a source of omega-3 (n-3) fatty acids, very long chain polyunsaturated fatty acids which are critical for the development of the brain and retina, and which may be protective of some chronic diseases. Eicosapentanoic acid (EPA) (20:5 n-3) and docosahexanoic acid (DHA) (22:6 n-3), which account for approximately 90% of the polyunsaturated fatty acids in fish species from the North Atlantic and North Pacific (Sabry, 1990), are absent or present in much lower amounts in other foods. The amount of cholesterol found in fish is comparable to levels in beef, pork, and chicken. Fish is an excellent source of the B vitamins niacin and B12, and in general is a better source of Vitamins D and A than beef, pork or chicken. Fish can also contribute appreciable amounts of dietary calcium, heme iron and zinc, nutrients that tend to be low in people's diets. Fish is among the best sources of dietary selenium.

These nutritional benefits are examined from a population health perspective (i.e., what is relevant to the healthy 'general population'), rather than a high-risk approach (which is primarily interested in individuals at highest risk of disease). The nutrient profiles of commonly consumed sport-caught fish are also compared with those of other protein sources, and discussed in terms of current population intakes and recommendations. A table that summarizes the nutrient content and contaminant concentrations of various species of fish and other foods is found at the end of this chapter. Finally, a brief discussion of the effects on nutritional quality and contaminant levels from how the fish is prepared and cooked is provided.

3.2 Per Capita Consumption of Fish (Finfish and Shellfish)

In the Continuing Survey of Food Intakes by Individuals (CSFII), the USDA regularly collects information from large numbers of respondents across the United States, about foods eaten. These consumption data (recorded as weights of the food item consumed for three consecutive days) provide estimates of the average amounts of finfish and shellfish eaten daily by various population sub-groups.

In 1996, the U.S. EPA published *Daily Average Per Capita Fish Consumption Estimates Based on the Combined USDA 1989, 1990, and 1991 CSFII* in their *Exposure Factors Handbook* (U.S.

EPA, 1997a). It contains summaries and weighted population estimates based on data collected from the 11,912 participants in these three national surveys. The U.S. EPA considers this "the key study for estimating mean fish intake" (U.S. EPA, 1997a), stating that the data "are probably adequate for assessing fish ingestion exposure for current populations."

These food consumption data are summarized for the survey respondents and weighted for extrapolation to the U.S. general population. Estimates of both uncooked fish weights and cooked fish weights are provided. The average cooked weight of fish (finfish and shellfish) eaten from freshwater and estuaries was estimated to be 4.7 grams (90% C.I. = 4.2-5.3) per person per day for the U.S. population. Among the 18.5% of survey participants who reported eating freshwater and estuarine fish, the average cooked weight consumed was estimated to be 68.0 g/day (90% C.I. = 61.9-74.1; Tables 10-11 and 10-21, p.10-38 and 10-44). The average per capita intake of marine fish is 10.9 g/day (cooked weight; 90% C.I. = 10.1-11.7) for the U.S. population, and 87.8 g/day (90% C.I. = 83.7-91.8) among those 30.1% of survey participants who reported eating marine fish (Tables 10-11 and 10-22, p. 10-38 and 10-44). Overall, 37% of individuals reported eating fish (from all sources); on average, they ate an estimated 100.6 grams of (cooked) fish a day (Table 10-23, p.10-45). Perhaps not surprisingly, males ate higher amounts of freshwater/estuarine, marine and all fish (77.5 g/day, 98.6 g/day, and 114.2 g/day respectively) than females (58.8 g/day freshwater/estuarine; 78.5 g/day marine; 88.5 g/day all fish).

The U.S. per capita consumption of fish since 1977/78 has been approximately 11 g/day (U.S. EPA, 1997a, p.10-5), ranging from 4 g/day for children aged 0-5 years, to 12 g/day and 15 g/day among females and males aged 20 and older, respectively (Table 10-46, p.10-56). Geographically, slightly higher rates of fish consumption are found in New England and the Atlantic states, than in the rest of the U.S.

Preliminary analyses conducted on data from the most recent CSFII survey (1994-96) suggest that the per capita consumption of fish may have fallen slightly, from 11 to 9 g/day (Borrud et al., 1996). This is, on average, about the same as pork with a per capita consumption rate of 11 g/day (down considerably from 20 g/day in 1977/78). Beef consumption has declined dramatically over the past 20 years, from 52 g/per person/per day to 24; this is approximately the same as chicken, with an average per capita consumption rate of 23 g/day.

These shifts in dietary patterns have led to a drop in the percentage of energy (calories) from fat (from 40% in 1977-78 to 34%) and saturated fat (from 12 to 11%), and an increase in the percentage of energy from carbohydrates (from 43 to 51%). While these changes still do not meet current recommendations for “no more than 30% of energy from fat, 10% of energy from saturated fat, and at least 55% of energy from carbohydrates”, they are important and healthful changes. However, the same data suggest that average intakes of vitamin B6, calcium, iron, zinc, and some other nutrients are below the Recommended Daily Intakes (RDAs). As the study authors explain, "as the percentage of the population with intakes below 100% of a given RDA increases, so does the likelihood that some people are at nutritional risk. Only 21% of the women in the 1994 CSFII had diets that met the RDA for calcium... and 17% for zinc" (Borrud et al, 1996, p.17).

3.3 Nutritional Content and Contaminant Levels for Fish and Other Protein Sources

3.3.1 Selection of Nutrients, Foods and Contaminants for Tables 3-1 and 3-2

Tables 3-1 and 3-2 (found at the end of this chapter on pages 3-14 and 3-18) were designed to facilitate the comparison of the nutritional components and contaminant levels in several fish species, to levels present in other commonly consumed foods of high protein quality. Ocean fish and seafood species were chosen to represent commonly consumed store-bought fish (e.g. halibut and tuna) as well as species commercially or sport caught in specific geographical regions (e.g., crab). Freshwater fish species selected represent commonly consumed sport-caught fish occurring in various geographical locations across the United States, and include species of varying fat content. Other foods present in the table, such as beef tenderloin, pork loin, and chicken breast, were chosen as lean protein sources that could be compared with lean fish species (e.g. walleye). Fast foods and processed foods such as fried chicken, hamburgers, hotdogs, and fish sticks are important sources of protein for a large segment of the population. Other foods, such as tofu and refried beans, were included because they may be important protein sources for specific ethnic groups.

The nutrients listed in Tables 3-1 and 3-2 represent the most important nutrients commonly obtained from fish, which could be regarded as public health concerns. In other words, fish would be considered good sources of these nutrients, which, according to U.S. population surveys, are often not consumed in recommended amounts. Fish do supply other important micronutrients and compounds, such as fluorine and copper, which are not currently public health nutrition concerns in the U.S. A detailed discussion of specific nutrients can be found in subsequent sections of this chapter. By comparing the protein (and associated indices such as protein efficiency ratio), vitamin, mineral and lipid (e.g. omega-3 fatty acids) levels in fish to those of other protein food sources, the nutritional benefits of consuming various protein sources can be assessed.

The nutrient compositions of the foods listed in the table were obtained from the USDA's food composition database (USDA, 1998). To create a nutrition profile for a given food, data are compiled from several sources. For example, the data on fish are obtained from the scientific literature, government agencies outside the USDA, USDA contracts, and industry and trade associations (J. Exler, personal communication, 26 April, 1999). Several sources of data are compiled to help make the samples more representative of fish obtained throughout the U.S. Values for cooked fish were calculated from data on raw fish. Fish species that are listed as "wild" were obtained from commercial sources or, if the wild form of the species was not available, the fish was caught by the group contracted to provide the sample. All values for the fish listed in the tables are for the "wild" form. For processed fish and other foods, data are available on the most popular brand names.

For the development of the framework, six chemical contaminants were chosen to represent toxic substances that may be present in various protein sources. By comparing the levels of contaminants in commonly consumed fish species to those in other commonly consumed protein food sources, the relative risk of exposure to contaminants through the consumption of various foods can be assessed. Contaminant levels in foods, including wild fish species, are monitored to identify foods that may contain unsafe levels. While published reports of contaminant levels in fish and other foods have been released as recently as 1998, the data used for many of these reports were collected in the late 1970s and early 1980s. Since the level of many of these contaminants in foods declined during those years (and the decline most likely continued throughout the 1990s) references that contained data collected in the late 1970s and early 1980s were not used in Tables 3-1 and 3-2. Data for a number of these chemical contaminants was not available.

3.3.2 Substituting Other Foods for Fish: Effects on Macronutrient Profiles

While it can be useful to compare the nutrients found in equal weights of various foods, it is the impact of substituting one for food another on the *total diet* that is important. For example, 24-hour food record for a 45 year old female of Asian descent, who had eaten 150 grams of rainbow trout for dinner was analyzed by a nutrient software program (Candat, 1994), and the results are shown in Table 3-3**.** Her total protein intake (from the fish and other foods eaten) on that particular day accounted for 24% of her energy intake (calories), while 37% of her calories came from fat and 39% came from carbohydrates. (Although this dietary profile does not meet current recommendations for diets composed of 30% or less of energy from fat and 55% or more of energy from carbohydrates, it is a typical North American dietary profile). Table 3-3 shows the effect of substituting 150 grams of perch (a lean herbivorous fish), skinless chicken breast, or hot dogs for the rainbow trout. The rainbow trout, a fattier fish species, and the skinless chicken breast produce daily dietary profiles that are similar. The best macronutrient profile is obtained with perch (i.e., the lowest % of energy from fat, highest % of energy from carbohydrates, and lowest total number of kcal), while substituting 150 grams of hot dogs produces the worst dietary profile. Thus, substituting a fatty or a lean species of fish for hot dogs at one meal can make a noticeable improvement in the profile of the whole day's diet, even if no other dietary changes are made.

Table 3-3. Percent of energy (calories) from macronutrients based upon one day's diet which included a 150 gram serving of fish, chicken or hotdogs.[1] (calculations based on Candat, 1994)

	Rainbow Trout	Perch Mixed Species	Chicken Breast (no skin)	Hotdog
% energy from Protein	24%	26%	27%	15%
% energy from Fat	37%	33%	34%	52%
% energy from Carbohydrates	39%	41%	39%	33%
Total energy intake for 24-hr	1148 kcal	1099 kcal	1171 kcal	1396 kcal

[1] based upon an actual 24-hr food record of a 45-year-old female.

3.4 Fish as a Protein Source

3.4.1 Protein Quality

As Groff et al. (1995) states, "The importance of protein in nutrition and health cannot be overemphasized." Protein is composed of amino acids; nine of these (leucine, isoleucine, valine, lysine, tryptophan, threonine, methionine, phenylalanine, and histidine) are considered nutritionally essential or "indispensable" in the human diet, because they cannot be synthesized by the body. Protein also supplies nitrogen, for the internal synthesis of other amino acids required by the body. Different categories of proteins include enzymes, required as catalysts in most of the body's chemical reactions, peptide hormones (such as insulin, thyroid hormones, and the growth hormone somatotropin), structural proteins (in muscle and connective tissue), transport proteins (e.g., albumin, transferrin, hemoglobin), and immunoproteins or antibodies.

The quality of a protein is mainly determined by the specific amounts and relative proportions of its essential amino acids, their availability to the body, and to a lesser extent, the protein's digestibility. While the amount of protein required by individuals depends on their body weight and height, energy (calorie) intake, and physiologic condition (e.g., infancy, pregnancy), it is the quality of the protein which is most important in determining daily requirements.

3.4.2 Fish Protein vs. Other Dietary Protein Sources

There are many ways of evaluating the quality of the protein provided by different foods, for comparison purposes. In general, protein from animal foods (e.g., dairy products, eggs, meats, fish, and poultry) is of higher quality than protein from plant foods (e.g., pasta, rice, fruits, and vegetables).

The Chemical Score or Amino Acid Score compares a food's amino acid pattern to that of whole egg protein (with a score of 100), considered to be have the 'ideal' reference composition. The Chemical Score of finfish is 70, an indication of its high quality; beef is 69 and cow's milk is 60 (Sabry, 1990).

The Biological Value (BV) of a protein is calculated by measuring the body's nitrogen balance--nitrogen ingested (from the protein of interest), absorption and use for synthesizing new amino acids, and losses (through urine and feces). The percentage of the absorbed nitrogen which is retained by the body for tissue growth and maintenance, is the BV:

$$BV = (\text{nitrogen retained}/\text{nitrogen absorbed}) \times 100$$

As shown in Tables 3-1 and 3-2, the BV of fish (76%) is slightly higher than that of beef (74.3), pork (74.0) and chicken (74.3), but all are somewhat lower than egg (93.7).

The Protein Efficiency Ratio (PER) is another measure of protein quality, usually calculated by putting young animals on diets with various test proteins, and monitoring their growth. The PER is a ratio of the gain in weight divided by the weight of the protein consumed:

PER = gain in body weight (in grams)/grams of protein consumed

The PER of fish (3.55) is higher than beef (2.30) and milk proteins (casein = 2.50), and close to that of egg (3.92).

3.5 Fish as a Source of Essential Fatty Acids

Although high fat intakes have been associated with an increase in the risk of several chronic diseases, a certain amount of fat is necessary for the body to function normally. Triglycerides provide the body with a continuous fuel source, supply heat to the body, protect the body from mechanical shock, and certain fatty acid components are important building blocks for several hormone regulators (Whitney and Rolfes, 1996). Phospholipids and sterols are a major component of cell membranes, and sterol cholesterol provides the building blocks for some hormones, Vitamin D, and bile.

Food is composed of saturated, monounsaturated and polyunsaturated fatty acids. In lean finfish (e.g., walleye and yellow perch) polyunsaturated fatty acids account for approximately 50% of the total fatty acid content in the flesh. Saturated and monounsaturated fatty acids each comprise approximately 25% of the total fatty acid content. For fattier finfish (e.g., channel catfish and rainbow trout) polyunsaturated and saturated fatty acids each constitute approximately 25% of the total fatty acid content. The amount of saturated fatty acids tends to be relatively constant across fish species with proportions of polyunsaturated fatty acids being lower in fish with higher levels of monounsaturated fatty acids (Sabry, 1990).

Finfish tend to have higher levels of polyunsaturated fatty acids and lower levels of saturated fatty acids than other meat sources of protein. The proportion of saturated, monounsaturated and polyunsaturated fatty acids found in beef and pork are, respectively, approximately 40-45%, 50%, and 4-10% (Sabry, 1990). The fatty acid profile of chicken (30-35% saturates, 35-40% monounsaturates, and 25-30% polyunsaturates) falls between that of fish and beef and pork. Dairy products (e.g., cheese and eggs) have a much higher saturated fat component (40-65%), similar monounsaturated levels (30-45%), and much lower polyunsaturated levels (5%) than fish.

Fish also contain long chain polyunsaturated fatty acids of the n-3 (or omega-3) series which are not commonly found in other food sources (Sabry, 1990). Eicosapentanoic acid (EPA) (20:5n-3) and docosahexanoic acid (DHA) (22:6n-3) are the most common n-3 fatty acids, and account for approximately 90% of the total polyunsaturated fatty acids in fish species from the North Atlantic and North Pacific (Sabry, 1990). Linolenic acid (18:3n-3), linoleic acid (18:2n-6) and arachidonic acid (20:4n-6) are also present in fish, although in much smaller proportions (i.e., 1-2%). In lean and lower fat fish (e.g., walleye and yellow perch), the n-3 fatty acid content (EPA + DHA) is often less than 0.5g/100g fish. For higher fat fish (e.g., coho salmon and rainbow trout) the fatty acid content is often between 0.8-1.0g/100g fish. These fatty acid components are absent or present in much smaller amounts in other protein food sources.

Linoleic and linolenic acid are essential fatty acids that are not produced in the body and must be obtained from dietary sources (Whitney and Rolfes, 1996). These fatty acids are an important part of the structural component of cell membranes, and are necessary for the formation of eicosanoids which assist in blood pressure regulation, blood clot formation, maintenance of blood lipid levels, and assist in the body's immune response.

Because studies have linked the type and amount of dietary fat to various diseases (e.g., cardiovascular disease), the fatty acid composition of fish has been of great interest to researchers for the past several years. The benefits of consuming the various types of fatty acids (and their component parts) found in fish are discussed in Chapter 2.

3.6 Cholesterol

Cholesterol forms the building blocks of several compounds (e.g., bile, sex hormones, adrenal hormones, and Vitamin D) with important physiological functions, and is a major structural component of cell membranes (Whitney and Rolfes, 1996). Although food provides an important source of cholesterol, endogenous sources contribute much higher amounts. Cholesterol is synthesized in the liver, through the production of bile, and in the intestine by *de novo* synthesis and desquamation of mucosal cells. The amount of endogenous cholesterol produced in the liver is dependent on the amount of raw materials available (i.e., carbohydrate, protein, and fat), the extent of bile production and availability of regulating hormones (e.g., insulin).

The amount of cholesterol found in finfish varies from approximately 50-100 mg/100 gram portion. This is comparable to the amounts found in beef (84 mg), pork (79 mg), and chicken (85 mg), and is somewhat lower than the levels found in cheddar cheese (105mg) and eggs (424 mg). The method of food preparation will also affect cholesterol levels. Deep frying, compared with dry heat cooking, increased the cholesterol level of channel catfish by approximately 10% (USDA, 1998).

3.7 Vitamins

3.7.1 Vitamins B3, B6, and B12

Vitamins B3 (niacin, nicotinic acid, nicotinamide) and B6 (pyridoxine, pyridoxal, and pyridoxamine) are water-soluble organic compounds that are absorbed into the portal blood and stored only briefly in the body; thus, they must be supplied in the human diet every day. Vitamin B12 (cyanocobalamin), also water-soluble, is available from animal foods and can also be re-absorbed into the bloodstream from bile and secretions in the small intestine (i.e., via enterohepatic circulation). It can be stored in the liver and other tissues for years.

Niacin is involved in hydrogen transfer reactions (as part of coenzymes NAD and NADP) and a deficiency results in diarrhea, dermatitis and dementia, a condition known as Pellagra. Adults require approx. 15-19 mg per day, according to the 1989 US Recommended Dietary Allowances. Sixty milligrams of the amino acid tryptophan are considered to be equivalent to 1 mg niacin and expressed as a niacin equivalent (NE).

Fish is an excellent source of niacin. A 100 gram portion of canned tuna supplies 13.280 mg of niacin, which compares favorably with another good source, chicken (13.712 mg). The same portion size of channel catfish or coho salmon supplies 7.95 mg of niacin, in contrast to beef tenderloin (3.92 mg), pork loin (5.243 mg), fortified pasta (1.672 mg), or egg (0.064 mg).

Vitamin B6 exists as several different chemical structures and their phosphorylated forms. Different forms of Vitamin B6 serve as important co-enzymes in transamination, decarboxlyation, and transulfhydration and desulfhydration reactions. The RDAs for adult males and females are 2.0 mg and 1.6 mg, respectively, and deficiencies are rare in North America.

The pyridoxine forms are found only in plant foods (especially bananas, navy beans, and walnuts), while the phosphorylated pyridoxal and pyridoxamine forms are found in animal foods, particularly coho salmon (0.568 mg/100 g) and roast chicken breast (0.600 mg/100 g). As shown in Table 3-1, 100 grams of fresh-water drum and rainbow trout (both 0.346 mg), halibut (0.397 mg) or canned tuna (0.350 mg) contain about the same amount of Vitamin B6 as pork (0.277 mg for a shoulder cut and 0.492 mg for a loin cut), beef (0.440 mg for tenderloin), ham (0.340 mg) or fast food chicken (0.350 mg). Even fish with lower amounts, such as channel catfish (0.106 mg) and northern pike (0.135 mg), compare favorably with the Vitamin B6 content of egg (0.121 mg) and are better sources than hot dogs (0.050 mg), cheddar cheese (0.074 mg), pasta (0.035 mg), and rice (0.093 mg).

Vitamin B12 or cyanocobalamin is produced by microorganisms in animals, and does not occur naturally in plant foods. It is important in three enzymatic reactions: the conversion of (1) homocysteine into methionine; (2) L-methylmalonyl CoA to succinyl CoA; and (3) the formation of leucine aminomutase. Little Vitamin B12 is lost through urine or feces; most is excreted into bile and then re-absorbed in the ileum. A deficiency occurs if absorption is impaired (e.g., with doses of 500 mg or more of Vitamin C), or after many years on a strict vegan diet, and results in megaloblastic anemia and neuropathy.

Sport-caught fish are among the best dietary sources of Vitamin B12; e.g., rainbow trout, coho salmon and channel catfish (6.3 ug, 5 ug, and 2.9 ug per 100 gram portions, respectively) provide more than beef (2.57 ug), pork (1.06 ug), chicken (0.34 ug), or egg (1.10 ug).

3.7.2 Vitamin A

Vitamin A (retinol, retinal, retinoic acid) is a fat-soluble vitamin, meaning that its absorption, transport and storage are linked to lipids (i.e., it requires bile salts for absorption, is transported as chylomicrons, and stored in fatty tissues). It is critical for good vision, growth, bone development and maintenance, T-lymphocyte function and antibody response, among other things.

Provitamin A refers to carotenoids found in plants and converted into retinol. Carotenoids such as lycopene and beta-carotene, which function as anti-oxidants, are thought to play a role in the prevention of some cancers. One Retinol Equivalent (RE) is the same as 1 microgram of all-trans retinol, 6 micrograms of all-trans beta-carotene, 12 micrograms of other provitamin A carotenoids and 3.33 International Units (IU) of pre-formed Vitamin A. According to the 1989

RDAs, adult males and females require 1,000 and 800 micrograms RE, respectively, each day. The vitamin A content of sport-caught fish depends on the fattiness of the species and the type of preparation for cooking (i.e., skin on vs. off, internal organs consumed). Relatively lower-fat species, such as yellow perch, contain smaller amounts of Vitamin A (10 RE per 100 g portion) in comparison with higher-fat species, such as coho salmon (39 RE), bass (35 RE) and fresh-water drum (59 RE). In general, fish is a better source of this vitamin than beef, pork, or chicken.

3.7.3 Vitamin D

Vitamin D is a fat-soluble sterol that occurs naturally in many forms. It is ergosterol when found in plants, while in animals and humans, it is synthesized in the skin as 7-dehydrocholesterol and upon exposure to sunlight is subsequently converted to precalciferol, then cholecalciferol. This is later converted by the liver to the active form, calcitriol. Vitamin D behaves like a steroid hormone to control blood levels of calcium, and thus has effects on bone, kidney, and intestinal tissues. A deficiency of Vitamin D interferes with the body's absorption of calcium and perhaps also phosphorus, which results in bone demineralization.

Fish is among the best food sources of Vitamin D, but few data are available in food composition tables. A 100 g portion of herring and tuna provide 22 and 6 micrograms, respectively, of Vitamin D. In contrast, the same amount of Vitamin D-fortified milk and liver provide only 1 and 0.1-0.2 micrograms, respectively.

3.8 Minerals

While fish is known to contain many important trace elements, only those minerals that are frequently lacking in the diets of healthy populations are presented here.

3.8.1 Calcium

An estimated 99% of the body's calcium resides in the teeth and bones, where it is extracted and re-deposited as needed to keep blood levels of calcium constant. The one percent found in the blood, lymph and other body fluids is critical to the intracellular and extracellular environments of all living cells. The parathyroid hormone, calcitonin, calcitriol (Vitamin D) and other hormones help to regulate levels by releasing calcium from bone and controlling its absorption from the intestine and excretion in urine, feces and sweat. Bone loss occurs naturally with age, in both males and females; therefore, it is important that children and young adults achieve their optimum bone density so that age-related losses will not result in osteoporosis.

Many dietary factors affect the bioavailability of calcium; dietary fiber, phytic acid, uronic acid and oxalic acid are believed to reduce intestinal absorption. Calcium is poorly absorbed (5%) from spinach, for example, which is high in oxalic acid, but more readily available from kale, which is low in oxalic acid. Dairy products provide about one-half of dietary calcium in the U.S. Fish with soft bones can also be important dietary sources; for example, walleye, bass and yellow perch provide 141, 103 and 102 mg of calcium, respectively, in a 100 gram portion. Small fish eaten whole, such as sardines and smelts, as well as canned fish with bones, such as salmon, also contribute appreciable amounts of dietary calcium.

3.8.2 Iron

In North America and worldwide, iron deficiency is the most prevalent nutritional deficiency (Yip and Dallman, 1996), particularly among young children and premenopausal women. Men typically have approximately 3.8 grams of iron in their bodies, one-third of which is stored as ferritin and hemosiderin in the liver, bone marrow and spleen, and two-thirds of which is functional iron, mostly in the form of hemoglobin and myoglobin. Women's bodies have about 2.3 grams of iron, and only about one-eighth (0.3 grams) is in storage. The body's increased demand for iron in pregnancy (1.0 gram) is much greater than the average woman's iron stores. In situations such as this, when the body's functional needs for iron outstrip bodily stores, iron deficiency may result. Measures of serum ferritin indicate when body stores of iron are low or depleted (iron depletion). When transferrin saturation falls, erythrocyte protoporphyrin levels rise, but hemoglobin levels are normal, resulting is iron deficiency without anemia. Iron-deficiency anemia occurs when blood hemoglobin levels have also dropped below normal values.

On average, men absorb only 6% of the dietary iron they consume; the rest is not soluble and thus not bioavailable. Premenopausal women absorb about 13% of their dietary iron, which helps to offset their smaller body stores. Fish and other animal foods contain heme iron, which only accounts for about 15% of dietary iron (85% is nonheme) but which is absorbed at over twice the rate of nonheme iron. Further, the presence of fish, meat, or poultry in a meal greatly increases the bioavailability of the nonheme iron provided by plant foods.

As seen in Table 3-1, fish species differ in the amount of dietary iron they provide--channel catfish has 0.35 mg/100 grams while the same size portion of bass contains 1.91 mg. In general, fish contains less iron than beef, but comparable levels to pork and chicken. Although dietary iron levels are similar in eggs, the iron has poor bioavailability.

3.8.3 Zinc

Zinc is part of many enzymes, biomembranes, and is involved in RNA transcription, among other activities too numerous to mention here. It has held tremendous public health significance in developing countries since the 1960s, when zinc deficiency was linked to stunted growth and delayed sexual maturation. Inadequate intakes of zinc are common in North America, particularly among vegetarians and adult women (e.g., Borrud et. al, 1996). While quite widely distributed among plant and animal foods, zinc often has low bioavailability because of its interactions with copper, iron, and other food components such as phytates.

Animal foods provide approximately 70% of the dietary zinc in the U.S., and in general, foods rich in protein are also good sources of zinc. As shown in Tables 3-1 and 3-2, sport-caught fish contain from 0.51-1.43 mg of zinc per 100 gram edible portions, comparable to levels in eggs, tofu, refried beans, pasta and rice.

3.8.4 Selenium

Selenium is found in different forms in plants (mainly as selenomethionine) and animals (mainly as selenocysteine). Animals and humans rely exclusively on dietary sources of the mineral, which is an important component of the enzyme glutathione peroxidase and some transfer RNAs, and functions as an anti-oxidant. There is also some evidence that it may form complexes with mercury, cadmium, and other toxic heavy metals (Levander & Burk, 1991).

Seafood and organ meats (e.g., liver) are the best dietary sources of selenium (40-150 micrograms per 100 gram portions). Beef and pork have lower levels (10-40 micrograms), and are followed by cereals and grains, <10 to >80 depending upon the soil content; dairy products, <10 to 30; and fruits and vegetables <10 (Levander & Burk, 1991).

3.9 Effects of Food Preparation Methods on Nutritional Benefits

The type of cooking method may affect some nutritional components, while other components remain unaffected. During the cooking process fish flesh loses moisture, with the amount lost dependent on the fish species, the size of the piece and cooking method (Sabry, 1990). For finfish, cooking with dry heat results in a moisture loss of 22% of the original weight compared to a 21% loss with moist heat, or an eight percent loss with bread-fried cooking. Microwave cooking results in even higher moisture losses (i.e. 30-35%) than dry or moist heat cooking. Because the proportion of solids is increased with moisture loss, the concentrations of certain nutrients tend to be higher in cooked relative to raw fish. After adjustments for water loss have been made, however, cooking does not appear to affect the protein or total lipid levels. With the exception of poaching, which may cause a loss of some dissolved minerals when cooking water is discarded, the mineral content of cooked fish is usually not affected by the cooking process. Some vitamins may be destroyed during the cooking process but this is dependent on the method, duration, and temperature of cooking. For the B vitamins (i.e. thiamin, riboflavin, niacin, B6, and B12) a loss in the range of 0- 30% has been reported (Sabry, 1990). For vitamin A, a loss of 5-15% has been observed due to the cooking process. In general, cooking with high temperatures for long periods of time tends to cause the greatest loss of vitamins.

The fat content of fish may also be altered depending upon how it is prepared and cooked. A 100-gram portion of channel catfish that was breaded and fried had twice the amount of energy (calories), and four times the amount of fat than a similar portion that was cooked using dry heat (USDA, 1998). Breading and frying also significantly altered the proportions of lipids. The amount of saturated fat, monounsaturated fats, and polyunsaturated fats increased by 400 - 500% in the breaded and fried fish. Levels of omega-3 fatty acids also increased in the breaded and fried fish, although not as dramatically (i.e. 10-100%). When comparing the nutritional benefits of consuming various types of fish and other protein sources, it is important to consider the method of food preparation and any additional ingredients (e.g., oil for frying) that may be added to the final cooked product.

3.10 Effects of Food Preparation Methods on Contaminant Levels

The way fish is prepared and cooked can modify the amount of chemical contaminants consumed. Appendix E of *the U.S. EPA Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 2* (U.S. EPA, 1997b) discusses the available data; some of this information is presented here.

The degree to which contaminants bioaccumulate in different fish species is dependent on their methods of feeding, the ability of the fish to metabolize the contaminants and the fat content of the fish (U.S. EPA, 1997b). Trimming the fat, and removing the skin and the internal organs will help decrease the amount of lipophilic contaminants but will not reduce exposure to those contaminants that concentrate in muscle and other protein-rich tissues (e.g. mercury).

The method of preparing the fish for cooking and eating appears to be a major factor in reducing the amount of certain contaminants in standard fish fillets. For example, trimming and cooking brown trout reduced the Mirex and PCB content by 74% and 78%, respectively (U.S. EPA, 1997b). However, broiling reduced the Mirex content by 26% but resulted in no reduction in the PCB levels. Removing the skin before cooking also resulted in a further 17% reduction in alpha-chlordane levels in chinook salmon fillets, compared to fillets baked with the skin on. Toxaphene levels were reduced by 40% when lake trout fillets had the skin removed and were charbroiled. For smallmouth bass, DDE levels were reduced by 54% when the fillets were trimmed. For certain ocean fish such as bluefish, the PCB content of the fillets was decreased by 27% after cooking and removal of skin and oil drippings (Trotter et al., 1988). For five fish species from the Great Lakes region, Zabik and Zabik (1995) found a 30-100% reduction in dioxin levels depending on the type of cooking method used. Smoking removed the greatest amount of dioxin (i.e. 100%) while salt boiling resulted in the smallest reduction (i.e. 30%). Preparation methods have a significant influence on the amount of various contaminants present in a cooked fish fillet.

3.11 Conclusions and Research Needs

There are many nutritional benefits associated with eating fish, regardless of the species type. Unlike red meats, eggs and dairy products, fish provides very high quality protein *and* a `heart healthy' combination of fatty acids. Further, fish (both lean and fatty) is one of the few foods that contain n-3 (omega-3) fatty acids, a class of fatty acids that are essential for the development of the nervous system and that may have other beneficial health effects. Calcium, iron, zinc, vitamin A, niacin, vitamin B6, and vitamin D tend to be low in U.S. diets; fish supplies all of these vitamins and minerals, in addition to others.

Fish is known to be a good dietary source of selenium, but few reference data are published; more research into the role of selenium in human health is also needed. Nutrient databases contain a wide range of fish species, but samples used to obtain nutrient values are composites of cooked fish from various unknown locations. Nutrient values are generally expressed on the basis of a 100 gram cooked fish portion. This limits the extent to which comparisons can be made with contaminant data, which are usually based on raw tissue samples of wild fish gathered from specific geographic areas, and expressed as concentrations rather than on a weight basis.

We know that different methods of preparing and cooking fish will alter some of the organochlorine contaminant levels. Ideally, the same samples of prepared and cooked fish would be sent for both contaminant and nutrient analysis, and weighed records of amounts of the fish consumed would be kept to enable researchers to better assess the physiological risks and benefits to humans.

Table 3-1 Nutrition Values and Contaminant Levels in Fish - values for 100 g edible portion

	Coho Salmon	Rainbow Trout	Northern Pike	Walleye	Rainbow Smelt	Fresh-water Drum	Bass Mixed Species	Channel Catfish	Sunfish	Perch Mixed Species
Protein	23.4 g	22.9 g	24.7 g	24.5 g	22.6 g	22.5 g	24.2 g	18.5 g	24.8 g	24.9 g
Protein Efficiency Ratio[1]	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55
Biological Value[2]	76.0	76.0	76.0	76.0	76.0	76.0	76.0	76.0	76.0	76.0
Calories	139 kcal	150 kcal	113 kcal	119 kcal	124 kcal	153 kcal	146 kcal	105 kcal	114 kcal	117 kcal
Total fat	4.3 g	5.8 g	0.9 g	1.6 g	3.1 g	6.3 g	4.7 g	2.9 g	0.9 g	1.2 g
Saturated fat	1.1 g	1.6 g	0.2 g	0.3 g	0.6 g	1.4 g	1.0 g	0.7 g	0.2 g	0.2 g
MUFA=s	1.6 g	1.8 g	0.2 g	0.4 g	0.8 g	2.8 g	1.8 g	1.1 g	0.2 g	0.2 g
PUFA=s	1.3 g	1.8 g	0.3 g	0.6 g	1.1 g	1.5 g	1.4 g	0.6 g	0.3 g	0.5 g
18:2 Linoleic	0.056 g	0.288 g	0.041 g	0.033 g	0.058 g	0.199 g	0.112 g	0.142 g	0.019 g	0.014 g
18:3 Linolenic	0.055 g	0.187 g	0.027 g	0.018 g	0.063 g	0.146 g	0.142 g	0.096 g	0.013 g	0.015 g
20:4 AA	0.022 g	0.120 g	0.036 g	0.074 g	0.071 g	0.287 g	0.185 g	0.087 g	0.101 g	0.067 g
20:5 EPA	0.401 g	0.468 g	0.042 g	0.110 g	0.353 g	0.295 g	0.305 g	0.100 g	0.047 g	0.101 g
22:6 DHA	0.658 g	0.520 g	0.095 g	0.288 g	0.536 g	0.368 g	0.458 g	0.137g	0.092 g	0.223 g
Cholesterol	55 mg	69 mg	50 mg	110 mg	90 mg	82 mg	87 mg	72 mg	86 mg	115 mg
Zinc	0.560 mg	0.510 mg	0.860 mg	0.79 mg	2.12 mg	0.850 mg	0.83 mg	0.61 mg	1.99 mg	1.43 mg

Iron	0.610 mg	0.380 mg	0.710 mg	1.67 mg	1.15 mg	1.15 mg	1.91 mg	0.35 mg	1.54 mg	1.16 mg
Calcium	45 mg	86 mg	73 mg	141 mg	77 mg	77 mg	103 mg	11 mg	103 mg	102 mg
Vitamin A	39 RE	15 RE	24 RE	24 RE	17 RE	59 RE	35 RE	15 RE	17 RE	10 RE
Vitamin B_3	7.950 mg	5.770 mg	2.800 mg	2.810 mg	1.766 mg	2.862 mg	1.522 mg	7.950 mg	1.460 mg	1.900 mg
Vitamin B_6	0.568 mg	0.346 mg	0.135 mg	0.138 mg	0.170 mg	0.346 mg	0.138 mg	0.106 mg	0.138 mg	0.140 mg
Vitamin B_{12}	5.00 ug	6.30 ug	2.30 ug	2.31 ug	3.97 ug	2.31 ug	2.31 ug	2.90 ug	2.30 ug	2.20 ug
Chordane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DDT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorpyrifos	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dioxins	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lindane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCBs	NA	NA	NA	9.2-193.3 ng/g wet wt.[3]	NA	NA	NA	NA	NA	NA
Mercury	NA	NA	NA	187-793 ng/g wet wt.[3]	NA	NA	NA	NA	NA	NA

[1]Protein Efficiency Ratio - gain in weight divided by weight of protein consumed
[2]Biological Value - the percentage of absorbed nitrogen retained
[3]Dellinger, J.A. et al. 1996. The Ojibwa Health Study: fish residue comparisons for Lakes Superior, Michigan, and Huron. Tox. Ind. Health 12:393-402.
NA indicates Not Available

Table 3-1 (Cont.) Nutrition Values and Contaminant Levels in Fish - values for 100 g edible portion, cont.

	Tuna Canned in water	Cod (Atlantic)	Halibut	Flatfish (Flounder & Sole)	Haddock	Mackerel Mixed Species	Orange Roughy	Ocean Perch	Sardines	Blue Crab	Northern Lobster
Protein	25.5 g	22.8 g	26.7 g	24.2 g	24.2 g	25.7 g	18.9 g	23.9 g	24.6 g	20.2 g	20.5 g
Protein Efficiency Ratio[1]	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	NA	NA
Biological Value[2]	76.0	76.0	76.0	76.0	76.0	76.0	76.0	76.0	76.0	NA	NA
Calories	116 kcal	105 kcal	140 kcal	117 kcal	112 kcal	201 kcal	89 kcal	121 kcal	208 kcal	102 kcal	98 kcal
Total fat	0.8 g	0.9 g	2.9 g	1.5 g	0.9 g	10.1 g	0.9 g	2.1 g	11.5 g	1.8 g	0.6 g
Saturated fat	0.2 g	0.2 g	0.4 g	0.4 g	0.2 g	2.9 g	0.02 g	0.3 g	1.5 g	0.2 g	0.107 g
MUFA=s	0.2 g	0.1 g	1.0 g	0.2 g	0.2 g	3.4 g	0.6 g	0.8 g	3.9 g	0.3 g	0.160 g
PUFA=s	0.3 g	0.3 g	0.9 g	0.6 g	0.3 g	2.5 g	0.02 g	0.5 g	5.1 g	0.7 g	0.091 g
18:2 Linoleic	0.009 g	0.006 g	0.038 g	0.014 g	0.012 g	0.149 g	0.009 g	0.036 g	3.543 g	0.028 g	0.005 g
18:3 Linolenic	0.002 g	0.001 g	0.083 g	0.016 g	0.003 g	0.064 g	0.002 g	0.073 g	0.498 g	0.021 g	0
20:4 AA	0.034 g	0.028 g	0.178 g	0.048 g	0.029 g	0.104 g	0.002 g	0.005 g	0	0.084 g	0
20:5 EPA	0.047 g	0.004 g	0.091 g	0.243 g	0.076 g	0.653 g	0.002 g	0.103 g	0.473 g	0.243 g	0.053 g
22:6 DHA	0.223 g	0.154 g	0.374 g	0.258 g	0.162 g	1.195 g	NA	0.271 g	0.509 g	0.231 g	0.031 g
Cholesterol	30 mg	55 mg	41 mg	68 mg	74 mg	60 mg	26 mg	54 mg	142 mg	100 mg	72 mg
Zinc	0.77 mg	0.58 mg	0.53 mg	0.63 mg	0.48 mg	0.86 mg	0.96 mg	0.61 mg	1.31 mg	4.22 mg	2.92 mg
Iron	1.53 mg	0.49 mg	1.07 mg	0.34 mg	1.35 mg	1.49 mg	0.23 mg	1.18 mg	2.92 mg	0.91 mg	0.39 mg

Table 3-1 (Cont.) Nutrition Values and Contaminant Levels in Fish - values for 100 g edible portion, cont.

Calcium	11 mg	14 mg	60 mg	18 mg	42 mg	29 mg	38 mg	137 mg	382 mg	104 mg	61 mg
Vitamin A	17 RE	14 RE	54 RE	11 RE	19 RE	14 RE	24 RE	14 RE	67 RE	2 RE	26 RE
Vitamin B_3	13.280 mg	2.513 mg	7.123 mg	2.179 mg	4.632 mg	10.667mg	3.654 mg	2.436 mg	5.245 mg	3.300 mg	1.070 mg
Vitamin B_6	0.350 mg	0.283 mg	0.397 mg	0.240 mg	0.346 mg	0.381 mg	0.346 mg	0.270 mg	0.167 mg	0.180 mg	0.077 mg
Vitamin B_{12}	2.990 ug	1.048 ug	1.366 ug	2.509 ug	1.387 ug	4.230 ug	2.310 ug	1.154 ug	8.940 ug	7.300 ug	3.110 ug
Chordane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DDT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorpyrifos	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dioxins	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lindane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCBs (Total)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mercury	<0.10-0.75 ppm[3]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[1]Protein Efficiency Ratio - gain in weight divided by weight of protein consumed
[2]Biological Value - the percentage of absorbed nitrogen retained
[3]Dellinger, J.A. et al. 1996. The Ojibwa Health Study: fish residue comparisons for Lakes Superior, Michigan, and Huron. Tox. Ind. Health 12:393-402.
NA indicates Not Available

Table 3-2 Nutrition Values and Contaminant Levels in Other Protein Sources - values for 100 g edible portion

	Chicken (brst, roast)	Lamb (shank & sirloin)	Beef (tenderloin)	Pork (loin)	Pork (shoulder)	Ham (sliced)	Sausage (turkey)	Sausage (pork link)	Bacon	Fish Sticks
Protein	31.0 g	28.3 g	28.3 g	28.6 g	25.6 g	17.6 g	14.4 g	16.3 g	30.5 g	15.7 g
Protein Efficiency Ratio[1]	NA	NA	2.30	NA	NA	NA	NA	NA	NA	NA
Biological Value[2]	74.3	NA	74.3	74.0	74.0	74.0	NA	74.0	74.0	NA
Calories	165 kcal	191 kcal	222 kcal	210 kcal	259 kcal	182 kcal	160 kcal	343 kcal	576 kcal	272 kcal
Total fat	3.6 g	7.7 g	11.2 g	9.8 g	16.6 g	10.6 g	9.6 g	30.5 g	49.2 g	12.2 g
Saturated fat	1.01 g	2.8 g	4.2 g	3.6 g	6.0 g	3.4 g	2.7 g	10.7 g	17.4 g	3.1 g
MUFA=s	1.2 g	3.4 g	4.2 g	4.5 g	7.4 g	5.0 g	3.6 g	14.8 g	23.7 g	5.1 g
PUFA=s	0.8 g	0.5 g	0.4 g	0.8 g	1.5 g	1.2 g	2.7 g	3.7 g	5.8 g	3.2 g
18:2 Linoleic	0.590 g	0.410 g	0.340 g	0.680 g	1.260 g	1.040 g	2.420 g	3.130 g	4.890 g	2.738 g
18:3 Linolenic	0.030 g	0.050 g	0.040 g	0.020 g	0.050 g	0.170 g	0.260 g	0.550 g	0.790 g	0.172 g
20:4 AA	0.060 g	0.050 g	0.050 g	0.040 g	0.070 g	0	NA	NA	0.130 g	0.018 g
20:5 EPA	0.010 g	0	NA	0	0	0	NA	NA	0	0.086 g
22:6 DHA	0.020 g	0	NA	0	0	0	NA	NA	0	0.128 g
Cholesterol	85 mg	89 mg	84 mg	79 mg	95 mg	57 mg	64 mg	77 mg	85 mg	112 mg
Zinc	1.00 mg	4.94 mg	5.59 mg	2.48 mg	4.51 mg	2.14 mg	2.15 mg	2.60 mg	3.26 mg	0.66 mg

Iron	1.04 mg	2.12 mg	3.58 mg	0.91 mg	1.40 mg	0.99 mg	1.38 mg	1.72 mg	1.61 mg	0.74 mg
Calcium	15 mg	8 mg	7 mg	17 mg	36 mg	7 mg	26 mg	16 mg	12 mg	20 mg
Vitamin A	6 RE	0	0	2 RE	3 RE	0	0	0	0	31 RE
Vitamin B_3	13.712 mg	6.340 mg	3.920 mg	5.243 mg	4.070 mg	5.251 mg	NA	NA	7.322 mg	2.129 mg
Vitamin B_6	0.600 mg	0.170 mg	0.440 mg	0.492 mg	0.277 mg	0.340 mg	NA	NA	0.270 mg	0.060 mg
Vitamin B_{12}	0.340 ug	2.640 ug	2.570 ug	0.720 ug	1.060 ug	0.830 mg	NA	NA	1.750 ug	1.797 ug
Chordane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DDT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorpyrifos	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dioxins	NA	NA	0.6 ppt, wet wt.[3]	59.3 ppt wet wt.[3]	NA	59.3 ppt wet wt.[3]	NA	NA	NA	NA
Lindane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCBs (Total)	416 pg/g wet wt.[4]		528 pg/g wet wt.[4]	672 pg/g wet wt.[4]	NA	NA	NA	NA	NA	N
Mercury	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[1]Protein Efficiency Ratio - gain in weight divided by weight of protein consumed
[2]Biological Value - the percentage of absorbed nitrogen retained
[3]Research Triangle Institute. 1997. Toxicological profile for Chlorinated Dibenzo-p-dioxins. (Draft). p.384.
[4]Newsome, W.H. et al. 1998. Residues of polychlorinated biphenyls (PCB) in fatty foods of the Canadian diet. Food Addit. & Contam. 15(1):19-29.
NA indicates Not Available

Table 3-2 Nutrition Values and Contaminant Levels in Other Protein Sources - values for 100 g edible portion

	Hot Dog (plain)	Burger (double)	Chicken (fast food)	Fish Sandwich (fast food)	Kidney Beans	Refried beans	Pasta	Rice	Tofu (firm)	Yogurt (plain)	Cheddar Cheese	Egg (boiled)
Protein	10.6 g	17.0 g	21.9 g	10.7 g	5.2 g	5.5 g	4.8 g	2.7 g	15.8 g	3.5 g	24.9 g	12.6 g
Protein Efficiency Ratio[1]	NA	2.30	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.92
Biological Value[2]	NA	74.3	74.3	NA	NA	NA	NA	NA	NA	NA	NA	93.7
Calories	247 kcal	309 kcal	303 kcal	273 kcal	81 kcal	94 kcal	141 kcal	130 kcal	145 kcal	61 kcal	403 kcal	155 kcal
Total fat	14.8 g	15.9 g	18.1 g	14.4 g	0.3 g	1.3 g	0.7 g	0.3 g	8.7 g	3.3 g	33.1 g	10.6 g
Saturated fat	5.2 g	5.9 g	4.8 g	3.3 g	0.05 g	0.5 g	0.1 g	0.1 g	1.3 g	2.1 g	21.1 g	3.3 g
MUFA=s	7.0 g	6.9 g	7.5 g	4.9 g	0.02 g	0.6 g	0.1 g	0.1 g	1.9 g	0.9 g	9.4 g	4.1 g
PUFA=s	1.7 g	1.3 g	4.2 g	5.2 g	0.2 g	0.2 g	0.3 g	0.1 g	4.9 g	0.1 g	0.9 g	1.4 g
18:2 Linoleic	1.310 g	NA	3.840 g	4.821 g	0.067 g	0.132 g	0.249 g	0.062 g	4.339 g	0.065 g	0.577 g	1.188 g
18:3 Linolenic	0.432 g	NA	0.214 g	0.399 g	0.105 g	0.021 g	0.024 g	0.013 g	0.582 g	0.027 g	0.365 g	0.035 g
20:4 AA	NA	NA	0.083 g	NA	NA	0	0	0	NA	0	0	0.149 g
20:5 EPA	NA	NA	0.001 g	NA	NA	0	0	0	NA	0	0	0.005 g
22:6 DHA	NA	NA	0.023 g	NA	NA	0	0	0	NA	0	0	0.038 g
Cholesterol	45 mg	56 mg	91 mg	35 mg	0	8 mg	0	0	0	13 mg	105 mg	424 mg
Zinc	2.02 mg	3.25 mg	0.95 mg	0.63 mg	0.55 mg	1.17 mg	0.53 mg	0.49 mg	1.57 mg	0.59 mg	3.11 mg	1.05 mg

Iron	2.36 mg	2.59 mg	0.91 mg	1.65 mg	1.23 mg	1.66 mg	1.40 mg	1.2 mg	10.47 mg	0.05 mg	0.68 mg	1.19 mg
Calcium	24 mg	49 mg	37 mg	53 mg	27 mg	35 mg	7 mg	10 mg	205 mg	121 mg	721 mg	50 mg
Vitamin A	0	0	36 RE	19 RE	0	0	0	0	17 RE	30 RE	278 RE	168 RE
Vitamin B_3	3.720 mg	4.690 mg	7.35 mg	2.15 mg	0.502 mg	0.315 mg	1.672 mg	1.476 mg	0.381 mg	0.075 mg	0.080 mg	0.064 mg
Vitamin B_6	0.050 mg	0.180 mg	0.350 mg	0.070 mg	0.069 mg	0.143 mg	0.035 mg	0.093 mg	0.092 mg	0.032 mg	0.074 mg	0.121 mg
Vitamin B_{12}	0.520 ug	1.660 ug	0.410 ug	0.680 ug	0	0	0	0	0	0.372 ug	0.827 ug	1.10 ug
Chlordane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DDT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorpyrifos	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dioxins	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lindane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCBs (Total)	678 pg/g wet wt.[3]	428 pg/g wet wt.[3]	454 pg/g wet wt.[3]	NA	NA	NA	NA	NA	NA	NA	NA	867 pg/g wet wt.[3]
Mercury	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[1]Protein Efficiency Ratio - gain in weight divided by weight of protein consumed
[2]Biological Value - the percentage of absorbed nitrogen retained
[3]Newsome, W.H. et al. 1998. Residues of polychlorinated biphenyls (PCB) in fatty foods of the Canadian diet. Food Addit. & Contam. 15(1):19-29.
NA indicates Not Available

3.12 References

Borrud, L., E.C. Wilkinson, and S. Mickle. 1996. What we eat in America: USDA surveys food consumption changes. Food Review: 14-19.

Candat. 1994. Candat Nutrient Calculation System User's Manual. Godin, London, Inc.

Dellinger, J.A. et al. 1996. The Ojibwa Health Study: fish residue comparisons for Lakes Superior, Michigan, and Huron. Tox. Ind. Health 12:393-402.

Exler, J. 1999. Personal communication with Elaine Murkin. 26 April.

Groff, J.L., S.S. Gropper, and S.M. Hunt. 1995. Advanced Nutrition and Human Metabolism. West Publishing Co. Minneapolis/St. Paul, MN.

Levander, O.A. and R.F. Burk. 1994. Chapter 12: Selenium. In: M.E. Shils, J.A. Olson, & M. Shike, (eds). Modern Nutrition in Health and Disease, 8th ed. Williams & Wilkins. Baltimore, MD.

Newsome, W.H. et al. 1998. Residues of polychlorinated biphenyls (PCB) in fatty foods of the Canadian diet. Food Addit. & Contam. 15(1):19-29.

Research Triangle Institute. 1997. Toxicological profile for Chlorinated Dibenzo-p-dioxins. (Draft). p.384.

Sabry, J.H. 1990. Nutritional aspects of fish consumption. A report prepared for the National Institute of Nutrition. Ottawa, Canada.

Trotter, W.J., P.E. Corneliussen, R.R. Laski, et al. 1988. Levels of polychlorinated biphenyls and pesticides in bluefish before and after cooking. J. Assoc. Anal. Chem. 72: 501-503.

USDA. 1998. Nutrient Data Laboratory, Agricultural Research Service, Beltsville Human Nutrition Research Center. Online at: http://www.nal.usda.gov/fnic/foodcomp/

U.S. EPA. 1997a. Food ingestion factors. Exposure factors handbook, Vol. II. Office of Research and Development. EPA/600/P-95/002Fb.

U.S. EPA. 1997b. Appendix E: Dose modifications due to food preparation and cooking. In: Guidance for assessing chemical contaminant data for use in fish advisories, Volume II. Risk assessment and fish consumption limits, 2nd ed. Office of Water. EPA 823-B-97-009.
Whitney, E.N. and S.R. Rolfes. 1996. Understanding Nutrition. West Publishing Co. St. Paul, MN.

Yip, R. and P.R. Dallman. 1996. Chapter 28: Iron. In E.E. Ziegler and L.J. Filer (eds). Present Knowledge in Nutrition, 7th ed. International Life Sciences Institute. Washington, DC.

Zabik, M.E. and M.J. Zabik. 1995. Tetrachlorodibenzo-p-dioxin residue reduction by cooking/processing of fish fillets harvested from the Great Lakes. Bull. Environ. Contam. Toxicol. 55: 264-269.