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App Note

Trace Elements in Fish and Fish Oil Supplements

Abstract

For years, the American Heart Association has recommended eating an average of two to three fishmeals each week to help reduce cholesterol, high blood pressure, and hardening of arteries. Research shows that consuming fish increases high quality protein with fewer calories, and it is rich in omega-3 fatty acids. Omega-3 fatty acid helps to reduce the risk of coronary artery disease, helps in the treatment of bipolar disorder/ depression, and helps reduce inflammation in autoimmune diseases[1,4]. Fish are also low in sodium and a good source of potassium. Some examples of fatty, coldwater fish that are high in omega-3 fatty acids include salmon, mackerel, and herring.

Unfortunately, due to industrial pollution, many fish have high levels of contaminants including mercury, methylmercury, and PCBs (polychlorinated biphenyls), which are absorbed by surrounding waters and from foods they eat. Currently, the EPA limit for mercury in fish is 1 ppm. About 22% of all PCBs are in estuarine and coastal sediments, which accounts for 95% of the fish production(2). The EPA estimates up to 15% of mercury emissions from these utilities fall within 30 miles of a plant, and up to 50% falls within six hundred miles. The mercury bio-accumulates through the food chain and reaches the predator species. For example, a Nevada reservoir fish tissue sample shows an average of 0.47 ppm mercury; the EPA guidelines recommend limiting consumption of such fish to one 8-ounce meal per month for adults[3].

For humans, mercury and methylmercury are toxic and can damage the brain and the nervous system. Mercury poisoning symptoms include numbness in hands and feet, general muscle weakness, and vision, hearing, and speech damage. In extreme cases, insanity, paralysis, coma, and death follow. The U.S. Food and Drug Administration and the EPA advised pregnant women, and those who might become pregnant, to avoid certain fish known to be high in mercury. This study will investigate trace element concentrations, including heavy metal concentrations, in different types of fish and fish oil supplements available from local markets in New Jersey.

Experimental Conditions

The following fish were purchased from local markets in New Jersey and analyzed for trace metal contents including mercury: tuna, fresh wild Alaskan salmon, marlin steaks, fresh swordfish steaks, fresh black pearl salmon, farm raised organic salmon, and cryon frozen tuna. Subsamples were taken of each fish, processed in a closed environment with 15 mL of pure nitric acid, 10 mL of hydrogen peroxide, and 25 mL of pure water, and brought to 50 mL volume. Determination of trace elementals were done on 1:10 dilution samples using PerkinElmer DRC and PerkinElmer ICP-MS (Elan 6100). The control, Lake Superior fish tissue (NIST SRM 1946), was processed and analyzed the same as the test fish samples. Fish Oil Supplements from various manufacturers (including Walgreens' generic brand, Sundown, 21st Century, and Nature's Bounty) were also analyzed.

Results

Our study shows that there is no significant difference in mercury between various types of salmon. However, higher levels of mercury were found in frozen tuna versus fresh tuna (Table 1). The source of the frozen tuna plays a key role in determining mercury levels. For instance, U.S. tuna is generally lower in mercury than imported tuna from Latin America, exceeding the government limit of 1 ppm(5). In general, bigger fish are more likely to have more mercury in them than smaller fish, and fatty or oily fish are likely to contain more mercury than lean fish.

To gain an accurate picture of the health consequences of eating fish, mercury content is not the only safety

indicator. Other elements also affect the way mercury interacts with the human body; thus, these elements need to be taken into account. One such element is selenium. Selenium has an interesting affinity to bind with mercury, blocking the mercury from binding to other substances, such as brain tissue. This phenomenon is something of a mystery to scientists who are still trying to understand and explain how selenium cancels out mercury's toxicity. The conventional idea follows that once selenium is digested, it can locate and neutralize the mercury molecules. A study in Japan found that adding selenium to the diets of birds could protect them from large amounts of mercury; this relationship between selenium and mercury is a kind of toxicological antagonism(6).

Table 1. Mercury Levels in Various Fish Tested

Fish	Hg Content (mg/kg)
Fresh Wild Alaskan Salmon	0.045
Fresh Black Pearl Salmon	0.031
Farm Raised Organic Salmon	0.043
Marlin Steaks	2.89
Tuna	0.054
Frozen Tuna	0.191
Fresh Swordfish (Steaks)	0.973
NIST SRM (1946)	Recovery: 0.419 Expected: 0.433

Selenium is also an important nutrient for fish. If mercury is depleting selenium, the selenium is not available for creating enzymes that are crucial for cellular function. Thus, it is important to maintain enough free selenium to support selenium-dependent enzyme synthesis and activity(7). Fish are a high source of dietary selenium, and cooked fish does not affect or prevent the absorption of selenium when eaten(8). According to a study from Madison, WI, red snapper has the highest Se:Hg ratio, while swordfish has the least (Figure 1). Our study outlines the Se:Hg ratio in the fish purchased from the local markets in New Jersey (Figure 2). Fresh black pearl salmon and tuna have high Se:Hg ratio levels, while marlin and swordfish have low Se:Hg ratio levels.

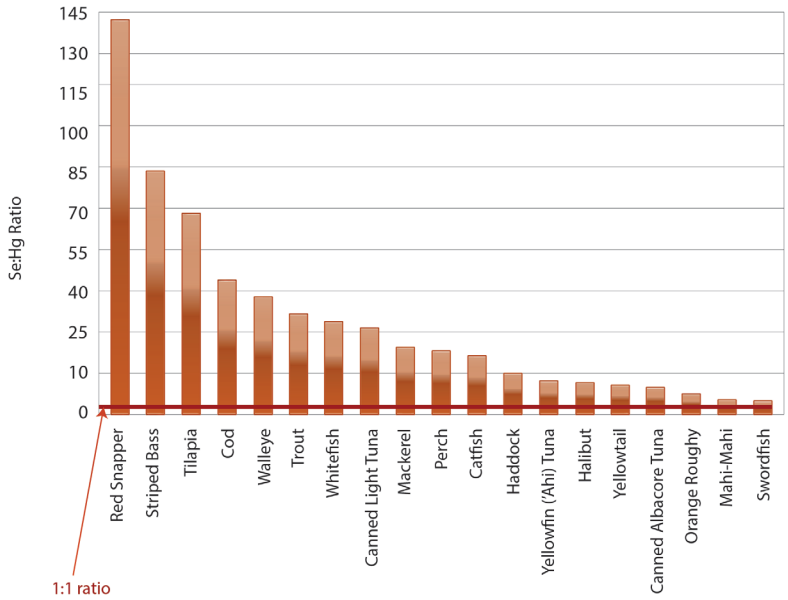

Figure 1. Figure 1. Mercury and Selenium Levels in Fish Analyzed From Madison, WI.(4)

Other elements were also tested in fish. Phosphorus in its phosphate form is an essential nutrient for many physiological processes; for instance regulating the body's acid-base balance, as a component of the cell structure (as phospholipids), in cell regulation and signaling, and in the mineralization of bones and teeth as part of the hydroxyapatite. Thus, fish is an excellent source of phosphorus (Table 3: 2500 to 4000 ppm phosphorus). A European study shows an average consumption of around 1,000–1,500 mg phosphorus per day. Magnesium is another essential element the body needs; it is a cofactor in hundreds of enzymatic reactions, some of which involve energy metabolism. It is also an essential component for the synthesis of protein and nucleic acid synthesis. Another bonus to eating fish is that it is low in sodium. An average adult needs about 1.5 g per day; however, in developed countries the range of sodium intake is 3 to 5 g due to high intake of processed foods.

Table 2. Moisture Content of Fish Tested.

Sample	Moisture (%)
Swordfish (light)	75.47
Swordfish (dark)	70.97
Salmon	69.39
Tuna	74.29
Tuna (dark)	73.96
NIST Sample	71.04
Sockeye Salmon	76.40
Marlin	76.83

Table 3. Contents of Other Elements in Various Fish Tested

Element	Tuna (dark) (ppm)	Fresh Wild Alaskan Salmon (ppm)	Marlin Steaks (ppm)	Fresh Swordfish Steaks (ppm)	Swordfish Skin (ppm)	Fresh Black Pearl Salmon (ppm)	Tuna Fish Frozen (ppm)	Black Pearl Salmon Farm Raised (ppm)
Al	6.113581	2.067156	1.151972	1.915496	1.226822	1.349939	2.292962	1.870572
B	0.371987	0.203485	0.120025	0.390736	0.213219	0.128711	0.387107	0.119194
Ba	0.483789	0.254131	0.143428	0.24469	0.128352	0.145466	0.10753	0.111978
Ca	65.75831	152.7416	40.62663	75.22529	43.45043	114.4878	47.87094	78.91483
Cd	0.034824	0.00333	0.051151	0.101939	0.137849	0.000123	0.014019	0.000919
Co	0.031684	0.009208	0.008478	0.008846	0.005574	0.007601	0.005795	0.005851
Cr	0.32677	0.256512	0.170128	0.181847	0.175906	0.17787	0.13205	0.149306
Cu	0.649259	0.43609	0.306776	0.41264	0.423247	0.386077	0.246721	0.341355
Fe	13.56378	4.757915	3.531584	3.002899	3.494471	4.165513	8.973148	2.267655
K	6708.052	4530.325	4079.669	3376.189	5704.003	4132.098	5467.929	5095.631
Mg	636.9343	405.3861	468.5556	370.6484	430.9387	330.192	456.6283	387.7597
Mn	0.241565	0.162041	0.130539	0.092151	0.099145	0.140655	0.073347	0.129186
Na	338.7067	775.1749	615.3617	1003.537	357.97	560.2424	212.8832	540.4338
Ni	0.157975	0.060019	0.03385	0.050989	0.064314	0.039795	0.036383	0.032219
P	4344.625	3062.008	3022.216	2395.497	3237.809	2565.016	3150.212	3081.3
Pb	0.11904	0.02269	0.022472	0.016598	0.00747	0.012271	0.010499	0.007915
Se	0.582097	0.306202	1.450984	0.479333	0.51366	0.243906	0.64918	0.168939
Zn	6.893357	4.721379	4.994995	6.817013	7.31882	4.668187	3.161439	4.469109

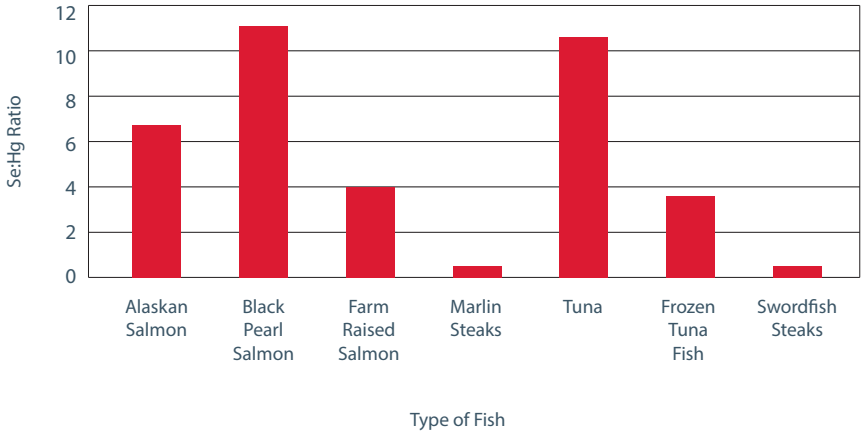

Figure 2. Fresh Black Pearl Salmon and Tuna Have High Se:Hg Ratio Levels, While Marlin and Swordfish Have Low Se:Hg Ratio Levels.

Several trace element s are found in fish, including aluminum, boron, cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead, and zinc. Several of these elements are beneficial as nutrients for humans; however, further investigation needs to be carried out to determine if the level of these elements are harmful to humans and how these elements interact with mercury. Table 3 data is reported on a wet (as received) basis; however, results can be converted to a dry mass on the basis of moisture content highlighted in Table 2.

Many people take fish oil supplements as a safe assurance of getting all the essential benefits without the risk of toxicity from eating a fish. Our study confirms that the fish oil supplements we analyzed do not contain mercury (Table 4). Published reports from Medscape Medical News by Dr. Laurie Barclay states that the fish oil supplements they analyzed (Omega Brite, Kirkland, Natrol, Sundown, and CVS) contained five times less PCB and 25 times less DDT than the FDA recommended limits of 2 ppm(9).

Conclusion

The health benefits of eating fish regularly outweigh the danger from mercury and other contaminants. In adults, the death rate from heart disease was 36% lower among those who ate fish twice a week as compared with those who ate little to no fish according to a study published in the Journal of the American Medical Association(10). Overall mortality was 17% lower. By following the recommendations listed below for selecting and eating fish, people will benefit from eating fish while knowing they have reduced their exposure to mercury(11).

1. Do not eat shark, swordfish, king mackerel, or tilefish, as they contain high levels of mercury.
2. Eat up to 12 ounces a week of the following fish that is low in mercury (two average meals): canned light tuna, salmon, pollock, and catfish.
3. Check local advisories on eating caught fish by friends and family in your local lakes, rivers, and coastal areas. If no advice is available, eat up to 6 ounces per week of the caught fish.

Table 4. Trace Elements in Fish Oil Supplements Tested.

Element	Walgreens (ppm)	Sundown (ppm)	21st Century (ppm)	Nature's Bounty (ppm)
As	0.36	0.3556	0.131	< 0.065
Ca	9.2	4.5325	6.835	4.95
Cd	< 0.0008	< 0.0007	< 0.0006	< 0.065
Cu	0.015	0.0042	< 0.0003	561
Fe	1.29	0.809	6.093	7.36
Hg	< 0.006	< 0.004	< 0.003	< 0.003
K	0.032	0.42	< 0.024	0.982
Mg	0.636	0.57	1.12	0.601
Mn	0.004	0.007	0.125	0.0267
Na	826	705	226	589
P	61	75.6	72.5	57.2
Pb	0.004	0.0035	0.002	0.02
Se	< 0.08	< 0.070	< 0.006	< 0.065
Zn	0.11	0.014	0.406	0.0601

References

(1) “Wellness Guide to Dietary Supplements”.

(2) Harvard Public Health Now, March 3, 2006.

(3) “Groups push probe of mining mercury emissions, Nevada Fisheries” Scott Sonner, Nctimes, 12/15/06.

(4) “The flip side of mercury” www.mercuryfacts.org.

(5) “Higher mercury found in imported tuna” The Associated Press, MSNBC.com, July 11, 2006.

(6) Mercuryfacts.org: Selenium: Mercury’s Magnet.

(7) “Mercury: selenium interactions and health implications” Laura J Raymond, PhD, Nicholas VC Ralston, PhD.: SMDJ, Special Issue, Vol. 7, No1, November 2004.

(8) “Bioavailability of selenium from fish...” European Journal of Clinical Nutrition: 2004 Feb; 58 (2): 343.

(9) “Fish Oil Supplements May be Safer than Eating Fish” Laurie Barclay, Medscape Medical News, January 27, 2007.

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(11) “Fish advisories” www.epa.gov.