Mercury and Fatty Acids in Canned Tuna, Salmon, and Mackerel

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ABSTRACT: Canned tuna (*n* = 240), salmon (*n* = 16), and mackerel (*n* = 16) were analyzed for mercury and fatty acids. Average mercury levels were 188, 45, and 55 ppb, respectively, and below the FDA Action Level of 1000 ppb. "Light tuna in water" contained lower mercury ($\bar{x}$ = 54 ppb) compared with "white/albacore tuna in water," which contained higher eicosapentaenoic acid/docosahexaenoic acid (EPA/DHA) $\bar{x}$ = 711 mg/100 g wet tissue). Mercury residues in salmon ($\bar{x}$ = 45 ppb) and mackerel ($\bar{x}$ = 55 ppb) were lower than in tuna products, but the EPA/DHA levels were higher (salmon, $\bar{x}$ = 1623 mg/100 g wet tissue; mackerel, $\bar{x}$ = 851 mg/100 g wet tissue). Information from this study will help women of childbearing age to limit their intake of mercury while obtaining healthy fats from fish.

Keywords: mercury, salmon, mackerel, tuna, EPA, DHA, omega-3 fatty acids

Introduction

In 2002, the United States per capita consumption of canned fishery products was 2.2 kg/y (NMFS 2002), with canned tuna (1.4 kg/y) being the 2nd most popular seafood (NFI 2001). Fish is a good source of dietary protein, vitamin D, and minerals (Saglik and Imre 2001; Kris-Etherton and others 2002). Fish consumption has been associated with improved pregnancy outcomes, as well as enhanced fetal growth rate (Burdge and others 1997; Olsen and Secher 1990, 2002; Horrocks and Yeo 1999; Allen and Harris 2001; Rogers and others 2004). The fetus and the nursing infant obtain long-chain omega-3 fatty acids from their mothers through placental exchange or breast milk (Helland and others 2001), and these fats are important for brain and retinal development (Olesen and Secher 1990; Helland and others 2001).

Fish is the major source of methylmercury in the diet with as much as 90% of the mercury in fish found as methylmercury (Voegborlo and others 1999; Plessi and others 2001; USEPA 2001). At high levels, methylmercury is toxic to the nervous system and developing brain (Zook and others 1976; Monterio and others 1997; USEPA 2001). Damage to the prenatal or postnatal nervous system can occur if the mother is exposed to excessive methylmercury during or before pregnancy or lactation (USEPA 1997, 2003; ATSDR 1999; NAS 2000). The fetal brain is sensitive to methylmercury, and adverse effects can be observed in the fetus at levels that appear to have no apparent adverse effect on the mother (Davidson and others 1998). Excessive prenatal exposure to methylmercury may cause developmental deficits in children (WHO 1990; Marsh and others 1995; USFDA 2000a, 2003). The U.S. Environmental Protection Agency (USEPA 2001) has established a Reference Dose (RfD) of 0.1 μg methylmercury/kg body weight/d. The CDC (2002) has reported that 8% of childbearing age women had higher blood mercury concentrations than recommended by the USEPA (that is, 5.8 μg Hg/L blood) (Schober and others 2003). Recently, the USEPA estimated that 15% of newborns (approximately 630,000) in the United States may have been exposed to excessive mercury when in the womb (Mahaffey 2004). Hence, exposure to methylmercury during pregnancy and early infancy is of particular concern.

Some fish provide long-chain omega-3 fatty acids; however, at the same time, sensitive populations should avoid eating fish that contain excessive mercury. Therefore, consumers, particularly women of childbearing age, should be aware of both the benefits and the risks from eating fish. The objective of this study was to determine the concentrations of mercury and fatty acids in canned tuna, salmon, and mackerel.

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Materials and Methods

Five brands of canned tuna (*n* = 240), 2 brands of canned salmon (*n* = 16), and 2 brands of canned mackerel (*n* = 16) were purchased from local stores around Lafayette, Indiana in 2003. Canned tuna included 4 types: light tuna in water, light tuna in oil, white/albacore tuna in water, and white/albacore tuna in oil. Five brands of canned tuna (3 lots of each brand) and 2 brands of salmon (1 lot of each brand) and mackerel (1 lot of each brand) were analyzed. From each lot, the total contents of 2 cans were combined and ground in a food processor with stainless-steel cutters (HC 3000, Protector-Silex, Inc., Washington, N.C., U.S.A.) to obtain a composite sample. One gram of each composite sample was analyzed in duplicate for total mercury using a Thermal Decomposition (Gold) Amalgamation Atomic Absorption Spectrophotometer (TDA/AAS) Mercury Analyzer (DMA-80, Milestone Inc., Pittsburgh, Pa., U.S.A.). Standard Reference Materials (SRMs: Tort-2 and Dorm-2, Inst. for Environmental Chemistry, Natl. Research Council Canada, Ottawa, Canada) were used to standardize the instrument. SRMs were included once for every 10 samples analyzed. Various amounts of Tort-2 with 0.270 ppm Hg and Dorm-2 with 4.64 ppm Hg were used to develop 2 calibration ranges (0 to 35 ng Hg and 30 to 470 ng Hg). The equation used to calculate mercury concentration in samples was Absorbance = Slope* ng Hg + Intercept, absorbance was measured at 253.7 nm. Equations $Y = 0.0245X + 0.0308$ ($R^2 = 0.9929$) for low range (0 to 35 ng Hg) and $Y = 0.0014X + 0.048$ ($R^2 = 0.9958$) for high range (30 to 470 ng Hg) were used to calculate mercury concentrations. The lower limit of detection for mercury in fish by TDA/AAS was 0.01 ng total Hg.

Table 1—Mercury residues and polyunsaturated fatty acids in canned fish[a]

Canned fish	Sample[b]	Total mercury[c] (ppb)	Total fat (%)	Fatty acids[d] (mg/100 g wet tissue) LA	ALA	SDA	ARA	EPA	DPA	DHA
Light tuna	1	52a	6.3	9[e]	4	3	20	32	10	181
	2	48a	6.4	6	6	2	38	36	22	277
	3	63a	7.6	7	5	3	43	39	14	300
	4	174b	6.8	3614	28	ND[f]	2	99	2	91
	5	191b	7.0	3047	40	ND	2	36	6	138
	6	340c	7.9	2625	50	ND	2	43	8	96
White/albacore tuna	7	227d	6.0	67	64	74	59	190	14	741
	8	232d	5.1	66	59	54	24	289	18	597
	9	330e	5.3	27	36	43	43	333	21	555
	10	220d	5.0	3228	136	19	21	58	7	181
Salmon	11	20	5.3	20	54	204	35	884	55	874
	12	70	4.7	70	122	398	78	925	10	564
Mackerel	13	61	4.9	61	48	64	50	553	40	649
	14	50	4.3	50	27	41	20	218	20	282

[a]Values within same type of tuna having different superscripts indicate a significant difference ($P < 0.05$).
[b]1 = chunk light tuna in water, Starkist®; 2 = chunk light tuna in water, Polar®; 3 = chunk light tuna in water, Kroger®; 4 = chunk light tuna in vegetable oil, Starkist; 5 = chunk light tuna in vegetable oil, Chicken of the Sea®; 6 = chunk light tuna in soy oil, Kroger; 7 = white albacore tuna in water, Bumble Bee®; 8 = white albacore tuna in water, Chicken of the Sea; 9 = white albacore tuna in water, pouch pack, Chicken of the Sea; 10 = white albacore tuna in soy oil, Bumble bee; 11 = pink salmon, Chicken of the Sea; 12 = fancy pink salmon, Polar; 13 = jack mackerel, Orleans®; 14 = jack jurel mackerel, Chicken of the Sea.
[c]Each value is the grand mean of duplicated 3 different lots including 4 composites (sample 1 to 10), each value is the mean of duplicated 4 composites (sample 11 to 14); limit of detection was 0.01 ng total Hg.
[d]ALA = α-linolenic acid (18:3n3); ARA = arachidonic acid (20:4n6); DHA = docosahexaenoic acid (22:6n3); DPA = docosapentaenoic acid (22:5n3); EPA = eicosapentaenoic acid (20:5n3); LA = linoleic acid (18:2n6); SDA = stearidonic acid (18:4n3).
[e]Standard deviation was less than +/-10% of mean values was not shown.
[f]ND = not detected at the lower limit of detection (1 mg fatty acids/g fat).

For determination of total fat, 2 composite samples were randomly chosen from each lot, thawed, and mixed well. A modified Folch method (Folch and others 1956; Gallina and others 2003) was used to determine total fat concentration. Five grams of composite tissue was mixed with 100 mL of chloroform/methanol (2:1, v/v, HPLC grade for chloroform, pesticide grade for methanol, Fisher Scientific, Fair Lawn, N.J., U.S.A.) for 2 h to extract the fat. The mixture was filtered (Whatman filter paper nr 1, 150-mm dia, Whatman Intl. Ltd. Maidstone, England) and 50 mL of 0.88% potassium chloride (ACS reagent, Sigma, St. Louis, Mo., U.S.A.) was added to the filtrate. After removing the aqueous layer (upper), the solvent (lower) was reduced by evaporation using a Turbo Vap® (Zymark Corp., Hopkinton, Mass, U.S.A.). The extract was transferred to a pre-weighed flask and placed in a desiccator overnight. Duplicated blanks were included in each run during the fat extraction. Ninety-five percent recovery of total fat was determined using a Standard Reference Material (SRM) (Lake Superior fish tissue 1946, Natl. Inst. of Standards and Technology, Gaithersburg, Md., U.S.A.). Determination of fatty acids was carried out using the AOAC method 991.39 (AOAC 2000). Polyunsaturated fatty acids, including linoleic acid (LA, 18:2n-6), α-linolenic acid (ALA, 18:3n-3), stearidonic acid (SDA, 18:4n-3), arachidonic acid (ARA, 20:4n-6), eicosapentaenoic acid (EPA) (all-*cis*-5, 8, 11, 14, 17-eicosapentanoic acid, 20:5n-3), docosapentaenoic acid (DPA, 22:5n-3), and docosahexaenoic acid (DHA) (all-*cis*-4, 7, 10, 13, 16, 19-docosahexaenoic acid, 22:6n-3) were quantified by gas chromatography with a flame ionization detector (GC/FID, Varian 3900 GC, CP-8400 auto sampler, CP-8410 auto injector, Varian Analytical Instruments, Walnut Creek, Calif., U.S.A.). Operating conditions were as follows: injection port temperature, 240 °C; detector temperature, 300 °C; oven programmed from 175 °C for 4 min to final hold temperature of 240 °C for 5 min with an increase of 3 °C/min; helium carrier gas (99.999% pure, Inweld, Inc., Lafayette, Ind., U.S.A.); and wall coated open tubular (WCOT) fused silica capillary column, 30 m × 0.32 mm, coated with Chrompack (CP) wax 52CB, DF 0.25 mm (CP 8843, Varian).

Statistical analyses including means, standard deviation, and *t* test were performed using SAS (version 8.0, SAS Inst. Inc., Cary, N.C., U.S.A.) at the significance level of $\alpha = 0.05$.

Results and Discussion

Mercury in "light tuna in vegetable oil" ranged from 174 to 191 ppb ($\bar{x} = 183$ ppb), which is 3 times higher than that found in "light tuna in water," which ranged from 48 to 63 ppb ($\bar{x} = 54$ ppb) (Table 1). "Light tuna in soy oil" contained significantly ($P < 0.05$) higher amounts of mercury ($\bar{x} = 340$ ppb) compared with "light tuna" packed either in water or vegetable oil. However, mercury residues in white/albacore tuna "in water" ($\bar{x} = 227$ ppb), "in spring water" ($\bar{x} = 232$ ppb), and "in soy oil" ($\bar{x} = 220$ ppb) were not significantly different. Foil pouches with "white/ albacore tuna in water" contained an average of 330 ppb of mercury. Mercury residues in canned tuna varied with the type of tuna (light or white/albacore) and packing media (water or oil). Overall, mean mercury in tuna ($n = 240$), salmon ($n = 16$), and mackerel ($n = 16$) were 188, 45, and 55 ppb, respectively. Mercury residues in salmon ranged from 20 to 70 ppb ($\bar{x} = 45$ ppb), whereas mackerel ranged from 50 to 61 ppb ($\bar{x} = 55$ ppb). None of the canned fish tested exceeded the FDA Action Level of 1000 ppb. Data reported here were comparable to past results ($\bar{x} = 170$ ppb in canned tuna) (USFDA 2001) but lower than those in a recent study that found 118 ppb in "light tuna in water" and 407 ppb in "white/albacore tuna" (Burger and Gochfeld 2004).

Total fat in canned fish ranged from 4.3% to 7.9% (Table 1). The content of polyunsaturated fatty acids in tuna, salmon, and mackerel were measured and expressed as mg of fatty acid per 100 g of wet tissue. Both "light tuna" and "white/albacore tuna" in either "vegetable oil" ($\bar{x} = 3330$ mg/100 g tissue) or "soy oil" ($\bar{x} = 2625$ mg/100 g tissue) contained higher contents of LA than tuna packed in water ($\bar{x} = 7$ mg/100 g tissue). The concentration of LA in salmon ranged from 69 to 141 mg/100 g tissue ($\bar{x} = 105$ mg/100 g tissue), whereas mackerel ranged from 27 to 80 mg/100 g tissue ($\bar{x} = 53$ mg/100 g tissue). The average concentrations of ALA in tuna, salmon, and mackerel were 43, 105, and 53 mg/100 g tissue, respectively. SDA was not detected in "light tuna in oil," but was found in "light tuna in water" ($\bar{x}$ = 3 mg/100 g tissue), "white/albacore tuna" in either water or oil ($\bar{x}$ = 47 mg/100 g tissue), salmon ($\bar{x}$ = 301 mg/100 g tissue), and mackerel ($\bar{x}$ = 53 mg/100 g tissue). The concentration of ARA ranged from 2 to 59 mg/100 g tissue ($\bar{x}$ = 25 mg/100 g tissue in tuna, $\bar{x}$ = 56 mg /100 g tissue in salmon, $\bar{x}$ = 35 mg/100 g tissue in mackerel). "White/albacore tuna in water" contained higher amounts of EPA ($\bar{x}$ = 271 mg/100 g tissue) compared with "white/albacore tuna in soy oil" ($\bar{x}$ = 58 mg/100 g tissue), "light tuna in water" ($\bar{x}$ = 36 mg/100 g tissue) or "light tuna in oil" ($\bar{x}$ = 59 mg/100 g tissue). EPA concentration in salmon ($\bar{x}$ = 904 mg/100 g tissue) and mackerel ($\bar{x}$ = 385 mg/100 g tissue) were higher than in tuna. The concentration of DPA ranged from 2 to 55 mg/100 g tissue in all canned fish ($\bar{x}$ = 12 mg/100 g tissue in tuna, $\bar{x}$ = 32 mg/100 g tissue in salmon, $\bar{x}$ = 30 mg/100 g tissue in mackerel). The concentration of DHA in "light tuna in water" ranged from 181 to 300 mg/100 g tissue ($\bar{x}$ = 253 mg/100 g tissue), whereas "light tuna in oil" was between 91 and 138 mg/100 g tissue ($\bar{x}$ = 108 mg/100 g tissue). DHA in "white/albacore tuna in water" ranged from 555 to 741 mg/100 g tissue ($\bar{x}$ = 631 mg/100 g tissue), whereas DHA in "white/albacore tuna in soy oil" averaged 181 mg/100 g tissue. DHA in salmon ranged from 564 to 874 mg/100 g tissue ($\bar{x}$ = 719 mg/100 g tissue), whereas mackerel contained 282 to 649 mg/100 g tissue ($\bar{x}$ = 465 mg/100 g tissue). The concentration of polyunsaturated fatty acids in canned fish was comparable to those reported by USDA (2001). EPA and DHA were the predominant polyunsaturated fatty acids in canned fish. Salmon and mackerel contained higher amounts of EPA and DHA than tuna products. Among the tuna products, "white/albacore tuna in water" ($\bar{x}$ = 902 mg/100 g tissue) contained the highest amounts of EPA plus DHA. However, this tuna had mercury levels that were 4 times higher than those in "light tuna in water," "salmon," and "mackerel."

Intake of mercury (% of RfD) and EPA/DHA based on current tuna consumption as estimated for a 60-kg woman are provided in Figure 1. The intake of canned tuna for the 95th and 99th percentiles of women (ages 15 to 44 y) is 20 g/d and 34 g/d, respectively (USFDA 2000b). The AI (Adequate Intake) for the omega-3 fatty acid, α-linolenic acid, during pregnancy or lactation is 1.4 or 1.3 g/d, respectively (NAS 2002). In addition, the recommendation is that EPA and DHA can contribute up to 10% of the AI for α-linolenic acid. Therefore, the effective AIs for pregnant and lactating women are 0.14 and 0.13 g/day, respectively. When a woman with a 60-kg body weight consumes an average of 20 g (95th percentile intake) of canned tuna per day, all of the tuna products tested would provide less than the RfD for mercury, and "white/albacore tuna" would provide sufficient EPA plus DHA. However, at the highest consumption level (99th percentile, 35 g/d), the daily intake of mercury would be 129% to 153% of the RfD ("light tuna in oil" or "white/albacore tuna"). In addition, when 8 oz/wk (32.43 g/d) is consumed, the mercury concentration in fish tissue should be below 185 ppb to remain below the RfD. Thus, low-mercury canned fish including "light tuna in water," salmon, and mackerel would be the best option for those that frequently consume canned fish. Less than a half meal (113 g) of salmon and mackerel per week provides sufficient EPA plus DHA.

Because young children are susceptible to the toxic effects of mercury, which may be found at moderate levels in canned fish, labeling of fish products that are low in mercury, such as "light tuna in water," salmon, and mackerel should be encouraged using a "kid-safe" emblem. This approach will be less likely to discourage consumers from eating fish but will help sensitive populations to consume those products that are lower in mercury residues.

Conclusions

Mercury residues in canned fish did not exceed the FDA Action Level of 1000 ppb. Mercury and omega-3 fatty acids in canned tuna varied with type of tuna and packing media. For childbearing-age women who are consuming canned tuna at the 99th percentile intake, white/albacore canned tuna can deliver up to 153% of the RfD for mercury. To protect at-risk populations, the Action Level for commercial fish should be reduced to 185 ppb or products exceeding this level should be labeled with an appropriate warning. To get sufficient EPA plus DHA without exceeding RfD, certain types of canned fish would be good options for pregnant and lactating women. In addition, the concept of a "kid-safe" label is supported for 1 type of tuna ("light tuna in water") due to the lower levels of mercury.

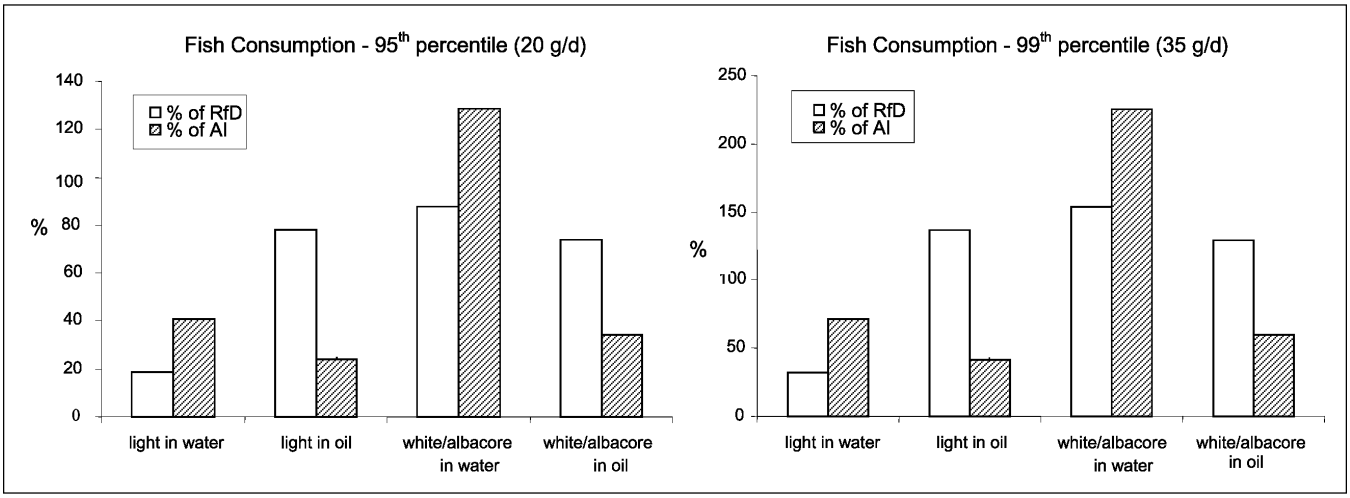

Figure 1—Mercury exposure (% of Reference Dose [RfD][a]) and intake of eicosapentaenoic acid (EPA) plus docosahexaenoic acid (DHA) (% of AI[b]) from consumption of canned tuna[c] by women of childbearing age. Fish Consumption–95th percentile (20 g/d), Fish Consumption–99th percentile (35 g/d). [a]RfD for methylmercury: 0.1 μg/kg/d (USEPA 2001); % of RfD was estimated based on 60 kg-bw individual. [b]Adequate Intake (AI) of EPA plus DHA for pregnant and lactating women: 0.13 to 0.14 g/d (10% of AI for α-linolenic acid) (NAS 2002).[c] Estimated intakes of canned tuna for women of childbearing age were 20 and 35 g/d for the 95th and 99th percentiles, respectively (USFDA 2000b).

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