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Mercury Concentrations in Three Species of Tunas Collected from Various Oceanic Waters

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In late 1970 and early 1971, a crisis faced the tuna fishing industry of the United States because potentially dangerous levels of mercury were found in certain species of canned tuna. Subsequent investigations by the National Canners Association (NCA), the Food and Drug Administration (FDA) and the National Marine Fisheries Service (NMFS) showed that only a small fraction of the total tuna production in the U.S. had mercury concentrations in the edible part (white flesh) of the tuna that exceeded the FDA "action level" of 0.5 ppm (µg/g, wet weight basis) of mercury.

While the primary effort of the NCA and FDA was involved with examination of the extent of the mercury problem in processed tuna, the NMFS was defining the mercury levels as they existed in the tuna resource at sea. A study was therefore initiated early in 1971 by the NMFS to relate mercury levels in tuna to such factors as species, size of fish, geographic area of catch and distribution within individual fish. The purpose of this report is to present the data that were accumulated.

MATERIALS AND METHODS

Sample Collection and Preparation

Frozen tuna were sampled at dockside holding facilities of various commercial fishing operations. A plastic coring device was fabricated for attachment to an electric drill. A plug of tissue (white flesh) about 1" in diameter and 1 ½" long was removed from three different locations on each tuna: 1) a sample of the loin muscle about two inches from the gill cover; 2) a sample of the loin muscle midway in the length of the fish; 3) a sample of the loin muscle several inches forward of the fork of the caudal fin. Samples from these locations were taken from all yellowfin and skipjack tuna, while only the midsection sample was taken from albacore tuna. Dark muscle (the reddish-colored flesh) was removed from the entire length of each fish and composited into a single sample. About one-fourth of the total liver was removed from most fish for analysis. Unfortunately, these sub-samples were taken randomly; no attempt was made to sample systematically the same portion of liver from each fish.

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All samples were packed in individual plastic bags, frozen and air-shipped to the laboratory. Frozen samples were then partially thawed and ground in an electric blender assembly, using a stainless steel cutting blade and glass jar. Both muscle and liver tissues were ground from individual tuna. Samples were not pooled.

Mercury Analyses

The samples were analyzed for total mercury concentration only, by the procedure of GREIG et al. (1975). This method was sensitive to about 0.05 ppm (wet weight) of mercury in fish.

Duplicate determinations of mercury were made on each muscle and liver sample. The precision of the analyses was measured by the relative standard deviation. A random selection of 25 duplicate analyses gave a mean relative standard deviation ± standard error of 8.9 ± 1.2%.

A sample of canned tuna obtained from the National Canners Association was analyzed with each batch of samples. This canned tuna sample had been analyzed by 12 separate laboratories and the mean mercury value obtained was 0.86 ppm (range 0.65-1.02). The mean and relative standard deviation obtained on 35 replicate analyses conducted over a period of several months by the methodology reported above was 0.90 ppm ± 17.1%.

DISTRIBUTION OF MERCURY IN SECTION OF TUNA MUSCLE

The mercury concentration data from samples described above were treated as follows: a ratio was computed by dividing the mercury concentrations in each of the anterior, posterior and dark muscle sections by the mercury concentration in the midsection for each tuna examined. Selection of the midsection as the divisor was arbitrary. These ratios provided a method of comparison for the distribution of mercury in the various sections of individual tuna. The results showed that, in general, the mercury concentrations were quite uniformly distributed along the length of the tuna, and mercury levels in both the dark muscle and white muscle were similar (Table 1).

Two noticeable exceptions, however, were the posterior section of skipjack tuna and the dark muscle of yellowfin tuna, both obtained from eastern Atlantic waters. The ratios of mercury concentrations in these samples to concentrations in the midsection were 1.37 ± 0.63 and 1.51 ± 0.71, respectively (mean ratio ± 95%

TABLE 1

Mercury Concentrations in Various Muscle Sections of Yellowfin and Skipjack Tunas.

Species / Catch location	Ratio of Mercury Concentrations in Muscle from Various Sections to Muscle from the Midsection of Tuna*			
	Anterior** section	Posterior** section	Dark** muscle	N+
	Average Ratio ± 95% Confidence Limits			
Yellowfin tuna				
Eastern Atlantic A++	1.19 ± 0.14	1.15 ± 0.31	1.51 ± 0.71	10
Eastern Atlantic B++	1.17 ± 0.16	1.06 ± 0.16	1.13 ± 0.17	20
Skipjack tuna				
Hawaii	1.06 ± 0.07	1.01 ± 0.08	1.02 ± 0.10	24
Eastern Atlantic C	1.14 ± 0.25	1.37 ± 0.63	1.06 ± 0.32	10

* For example: For each fish analyzed the mercury concentration in the anterior section was divided by the mercury concentration in the midsection.

** See text for preparation of muscle samples.

N+ Number of individual tuna examined.

++ Two collections from different areas were obtained; exact locations were not determined.

confidence limits). Thus, on the average, the mercury concentrations in these two samples were 40-50% greater than those found in other parts of the tuna. The data for these ratios, however, were quite variable; thus, the mean values provide only approximate relationships for the various samples examined.

GEOGRAPHIC VARIATION OF MERCURY IN TUNA

The mean mercury concentrations found in white flesh (midsection samples) and liver of skipjack, yellowfin and albacore tuna obtained from various geographic locations are presented in Table 2.

Skipjack tuna were obtained from two locations, eastern Atlantic and Hawaii waters, and no significant ($P = 0.05$) difference in mercury concentrations in muscle was observed for similar-sized fish (46-56 cm). The mean mercury level was 0.152 ppm for skipjack tuna obtained from eastern Atlantic waters and 0.211 ppm for those obtained from Hawaii.

Differences in mercury concentrations in the muscle and liver of yellowfin and albacore could not be attributed to geographic differences of catch because size of fish varied too greatly or there were too few fish from certain locations to provide valid comparisons.

RELATIONSHIP OF MERCURY CONCENTRATIONS TO SIZE OF TUNA

Mercury concentrations did vary as a function of length of tuna for certain species. Correlation coefficients show significant, positive correlation of these two variables for albacore (all locations) and skipjack from Hawaii (Table 3). A significant correlation was not found for yellowfin (both locations) and skipjack from the eastern Atlantic (Table 3). For these latter skipjack a possible reason no correlation was found was that the length range was small at 46-52 cm, compared to 52-76 cm for Hawaii skipjack.

DISCUSSION

Recently, PETERSON et al. (1973) published a review of mercury in tuna, which included data on the species examined in the present study, as well as other species of tunas. Comparison of the data given in the present study with those of PETERSON et al. (1973) is difficult because of differences in localities and in size of fish. Some collections of skipjack tuna were obtained from similar geographic locations for both studies and a comparison of the results is given in

TABLE 2

Mercury Concentrations in Three Species of Tuna from Pacific, Atlantic and Indian Oceans.

Species	Length (range) cm	Weight (range) kg	Catch Information Date	Location	Tissue	Mercury Concentration (ppm, wet weight) Mean	Std. Dev	N*
Skipjack	46-52	-	9/1970	Eastern Atlantic	muscle**	0.152	0.070	12
Skipjack	46-52	-	9/1970	Eastern Atlantic	liver	0.080	0.050	12
Skipjack	52-56	3.1- 3.6	12/1970	Hawaii	muscle	0.211	0.038	8
Skipjack	59-66	4.5- 6.8	12/1970	Hawaii	muscle	0.220	0.096	8
Skipjack	71-76	8.2-10.0	12/1970	Hawaii	muscle	0.359	0.082	8
Skipjack	52-56	3.1- 3.6	12/1970	Hawaii	liver	0.143	0.047	8
Skipjack	59-66	4.5- 6.8	12/1970	Hawaii	liver	0.165	0.060	8
Skipjack	71-76	8.2-10.0	12/1970	Hawaii	liver	0.270	0.094	8
Yellowfin	138-156	-	9/1970	Eastern Atlantic A+	muscle	0.350	0.135	15
Yellowfin	138-156	-	9/1970	Eastern Atlantic A	liver	0.321	0.284	14
Yellowfin	58-60	-	9/1970	Eastern Atlantic B+	muscle	0.158	0.039	6
Yellowfin	103-112	-	9/1970	Eastern Atlantic B	muscle	0.186	0.062	10
Yellowfin	103-112	-	9/1970	Eastern Atlantic B	liver	0.154	0.065	7
Albacore	55-69	-	8/1970	Oregon	muscle	0.295	0.060	7
Albacore	82-89	-	8/1970	Oregon	muscle	0.541	0.089	3
Albacore	78-88	-	10/1970	Indian Ocean	muscle	0.289	0.033	6
Albacore	89-99	-	10/1970	Indian Ocean	muscle	0.347	0.080	10
Albacore	102-109	-	10/1970	Indian Ocean	muscle	0.540	0.112	6
Albacore	80-98	-	10/1970	Ecuador-Peru	muscle	0.247	0.088	5
Albacore	106-110	-	10/1970	Ecuador-Peru	muscle	0.707	-	2

N* Number of individual tuna analyzed.

** Muscle sample was a core about 1½" in diameter taken from the muscle in the middle upper part of the tuna. See Table 1 for data on mercury concentrations in various muscle sections along length of tuna.

+ Yellowfin were collected from two areas in the eastern Atlantic (designated A & B); exact locations were not determined.

Table 4. In general, agreement is good for the reported mercury levels of the two studies. PETERSON et al. also found no published data on geographic variations in mercury levels of tuna. Our study did not provide strong evidence in this regard, but some information suggests no variation. No significant (P = 0.05) difference in mercury concentrations was found for skipjack tuna from eastern Atlantic waters in comparison to skipjack of similar size from Hawaii.

TABLE 3

Correlation Coefficients for Mercury Concentrations versus Fish Length for Various Tunas.

Species and location	Correlation coefficient for mercury level vs. fish size	Significant at P = 0.05
Skipjack, Eastern Atlantic	0.356	No
Skipjack, Hawaii	0.627	Yes
Yellowfin, Eastern Atlantic A	0.521	No
Yellowfin, Eastern Atlantic B	0.268	No
Albacore, Oregon	0.953	Yes
Albacore, Indian Ocean	0.739	Yes
Albacore, Ecuador-Peru	0.873	Yes

The analytical procedure used in the current study measured total mercury; thus, it did not distinguish between the more toxic form of methyl mercury and inorganic mercury. There are conflicting reports about the percentage of methyl mercury relative to total mercury in fish. Japanese investigators have reported that methyl mercury does not exceed about 15% of the total mercury in selected specimens of fish, while Swedish scientists reported that mercury consists mostly of methyl mercury in their fish (SUZUKI et al. 1973). RIVERS et al. (1972) studied methyl mercury and total mercury content of nine species of Pacific Ocean fish, including skipjack and yellowfin tuna, and found that "only Pacific blue marlin showed a large disparity between total and organic mercury levels in the muscle tissue."

Numerous marine fishes have been analyzed for total mercury and few species contained levels above 0.4 ppm, wet weight basis (ALEXANDER et al. 1973, CHILDS and GAFFKE 1973, FORRESTER et al. 1972, GREIG et al. 1975, PORTMANN 1972, WINDOM et al. 1973, ZITKO et al. 1971, ZOOK et al. 1976). Bluefish (Pomatomus saltatrix), lingcod (Ophiodon elongatus), spiny dogfish

TABLE 4

Comparison of Mercury Concentrations in Tunas Reported by Two Investigators.

Species and area	No. of specimens	Weight (kg)	Fork length (cm)	Mercury ppm, wet weight mean	Reference
Skipjack tuna					
Hawaii	8	3.1- 3.6	52-56	0.21	Present study
Hawaii	8	4.5- 6.8	59-62	0.22	Present study
Hawaii	8	8.2-10.0	71-76	0.36	Present study
Hawaii	20	-	-	0.38	PETERSON et al.
Hawaii	26	0.6- 1.8	-	0.15-0.38 (range)	PETERSON et al.

(Squalus acanthias), and red snapper (Lutjanus campechanus) were the principal species reported to have mercury levels in muscle above 0.4 ppm. In the present study, only a few specimens of albacore tuna were found with mercury levels above a mean of 0.4 ppm.

Some of the studies cited provided information on the relationship of mercury concentrations to size of fish. ALEXANDER et al. (1973) reported a significantly positive correlation between mercury levels in muscle and total weight for bluefish and striped bass. CHILDS and GAFFKE (1973) examined 13 species of fish, primarily sole and rockfish, and reported "no highly discernible linear correlation (i.e., correlation coefficient greater than 0.90) between either length or weight and mercury content was noted." In our study, no clear-cut relationship was found between mercury concentrations in muscle and fish length for yellowfin tuna. In the case of albacore and skipjack tuna there were indications of a linear relationship between mercury concentrations and fish length.

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REFERENCES

ALEXANDER, J. E., J. FOEHRENBACH, S. FISHER, and D. SULLIVAN: New York Fish and Game J. 20, 147 (1973).

CHILDS, E. A. and J. N. GAFFKE: Fish. Bull. U.S. 71, 713 (1973).

FORRESTER, C. R., K. S. KETCHEM, and C. C. WONG: J. Fish. Res. Board Can. 29, 1487 (1972).

GREIG, R. A., D. WENZLOFF, and C. SHELPUK: Pest. Monit. J. 9, 15 (1975).

PETERSON, C. L., W. L. KLAWE, and D. SHARP: Fish. Bull. U.S. 71, 603 (1973).

PORTMANN, J. E.: Aquaculture 1, 91 (1972).

RIVERS, J. B., J. E. PEARSON, and C. D. SHULTZ: Bull. Environ. Contam. Toxicol. 8, 257 (1972).

SUZUKI, T., T. MIYAMA, and C. TOYAMA: Bull. Environ. Contam. Toxicol. 10, 347 (1973).

WINDOM, H., R. STICKNEY, R. SMITH, D. WHITE, and F. TAYLOR: J. Fish. Res. Board Can. 30, 275 (1973).

ZITKO, V., B. J. FINLAYSON, D. J. WILDISH, J. M. ANDERSON, and A. C. KOHLER: J. Fish. Res. Board Can. 28, 1285 (1971).

ZOOK, E. G., J. J. POWELL, B. M. HACKLEY, J. A. EMERSON, J. R. BROOKER, and G. M. KNOBL, JR.: J. Agric. Food Chem. 24, 47 (1976).