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In a recent article,[3] data were presented on the concentrations of natural and artificial radionuclides in selected seafoods and FPC. We reasoned that the concentrates would be particularly interesting, since the industrial

Development (U.S. Government Printing Office: 1970) and Fish Protein Concentrate, A Comprehensive Bibliography (Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va.).

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College Park, Maryland. Gamma-ray emitting radionuclides were analyzed as received by counting 100-g aliquots of the concentrate (in duplicate) using NaI (Tl) detection systems. Iron-55 was determined by chemically isolating the iron in the sample[4] and then measuring the 5.9 keV X-ray which results from the de-excitation of its daughter, ^{55}Mn. Polonium-210 and ^{210}Pb were determined as previously described.[3] Polonium-208 and ^{212}Pb were used as yield monitors to account for any losses which occurred during chemical processing steps. Measurement of the alpha radioactivity was done using alpha spectrometry with surface barrier diodes.

Trace element analyses for all elements except iron were performed by atomic absorption spectrometry. Iron was determined colorimetrically,[5] using O-phenanthrolein as the color-forming agent. Duplicate 20-g samples of concentrate were wet ashed in redistilled, reagent grade concentrated nitric and perchloric acids or dry ashed in a muffle furnace at 460 C, depending upon the volatility of the element of interest. For the trace elements Co, Cu, Zn, Fe, Ag and Mn, dry ashing techniques were employed. For Cd and Pb, wet ashing with concentrated acids is preferred. Elemental concentrations were determined by the method of standard additions (Pb, Mn, Zn) or by comparing sample absorbances with those prepared from standard solutions (Ag, Cd, Co, Cu).

All radiometric data have been decay corrected to collection dates and the errors associated with these measurements are the standard errors (1σ) derived from a statistical analysis of the sample and background counting rates. The errors associated with the stable element analyses approach $\pm 5\%$ (based on agreements between duplicate samples and on samples to which known amounts of trace elements have been added).

RADIOACTIVITY MEASUREMENTS

The results of our radioactivity measurements are presented in Table 1. There are significant differences between the radionuclide content of these protein concentrates and those reported earlier.[3] In general, ^{137}Cs values for concentrates prepared from surface feeding fishes are not appreciably different from those prepared from inshore benthic fishes. Manganese-54 values are lower (possibly due to physical decay) while ^{55}Fe values are generally higher. The ^{90}Sr concentration of all the concentrates was <0.05 dis/min/g dry weight. Lead-210 and ^{210}Po values are comparable to those reported earlier, with the notable exception of the anchovy taken off the Southern California coast. The value of 57.7 ± 0.5 dis/min/g dry weight anchovy concentrate was confirmed by the analysis of an aliquot of this sample by C. W. Sill of the National Reactor Testing Station. This unusually high value was at first surprising, and we therefore analyzed various organs (pooled and individual) of fresh anchovy (*Engraulis mordax*) and saury (*Cololabis saira*) to determine the distribution of the ^{210}Po, ^{210}Pb and stable Pb in these fishes. Both species represent pelagic fishes whose diet consists mainly of planktonic crustacea.[6,7]

Table 2 clearly shows that in these fishes the majority of the ^{210}Po and ^{210}Pb activity, as well as stable lead, is found in the internal organs, principally the liver, bone, stomach contents and viscera (heart, intestine, spleen, kidney, stomach and gonad). The number in parenthesis indicates the number of specimens analyzed. The values of ^{210}Po observed makes the ^{210}Po content of the anchovy concentrate less surprising. Moreover, the stable lead content of the anchovy bone and liver substantiates the high stable lead value found in the anchovy concentrate. The lead specific activities (dis./min ^{210}Pb/μg Pb) of anchovy tissue range from 0.08 to 0.3, with the lead specific activity of the anchovy concentrate being 0.09. These values, and those of the saury and other concentrates analyzed here, approximate the range of lead specific activities found by TER HAAR *et al.*,[8] in their measurements of rain waters collected in the mid-western United States.

SHANNON *et al.*[9,10] have recently summarized their measurements of alpha radioactivity in marine organisms and water collected in South Africa. Although Shannon did not determine the partitioning of either ^{210}Pb or ^{210}Po into the various organs of the pelagic fishes analyzed, he did observe a mean ^{210}Po/^{210}Pb activity ratio of 157 for whole fishes. Our ^{210}Po/^{210}Pb activity ratios for the internal organs of anchovy and saury reported in Table 3

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Ocean Pout (*Macrozoarces americanus*)	Mass. Coast	Jan., 69	3.1 ±0.5	n.d.	0.16 ±0.04	1.3 ±0.3	0.17 ±0.06	1.3 ±0.02
Alewife (*Alosa pseudo harengus*)	Lake Michigan	April, 69	12.4 ±0.5	0.06 ±0.04	0.06 ±0.04	10.7 ±0.8	0.16 ±0.04	3.2 ±0.07
Gulf Menhaden (*Brevoortia patronus*)	Miss. Coast	May, 69	10.4 ±0.5	0.06 ±0.04	0.06 ±0.04	0.9 ±0.4	1.4 ±0.3	3.7 ±0.2
Anchovy (*Engraulis mordax*)	South California Coast	Jan., 69	8.0 ±0.4	0.15 ±0.05	n.d.	6.7 ±0.6	0.74 ±0.08	57.7 ±0.5
Atlantic herring (*Clupea harengus harengus*)	Mass. Coast	Nov., 68	11.9 ±0.5	n.d.	n.d.	11.2 ±0.8	0.07 ±0.02	0.2 ±0.06

n.d. not detectable.

Table 2. Polonium-210, Lead-210 and stable lead in pelagic fishes

Sample	Location	Collection date	Tissue	Radionuclide Concentration (dis/min/g dry weight) ^{210}Po	^{210}Pb	Stable Lead (μg/g dry weight)
Anchovy (*Engraulis mordax*)	Oregon Coast (46°30′) (124°14′)	27 May 1969	Muscle (13)	1.6 ± 0.1	<0.1	0.2
			Bone (13)	2.0 ± 0.3	2.0 ± 0.3	26.6
			Liver (10)	255.2 ± 19.2	1.8 ± 0.4	10.1
			Viscera (10)	158.9 ± 8.3	1.5 ± 0.08	<0.1
			Stomach contents (10)	29.1 ± 3.4	2.5 ± 1.0	<0.1
			Eviscerated whole fish (31)	6.7 ± 0.8	0.12 ± 0.05	0.4
Saury (*Cololabis saira*)	California Coast (35°10′) (122°23′)	16 Sept. 1969	Muscle (19)	4.3 ± 0.3	<0.1	0.2
			Bone (19)	0.9 ± 0.2	0.9 ± 0.2	5.0
			Liver (19)	53.1 ± 3.0	0.5 ± 0.2	3.9
			Viscera (19)	114.1 ± 7.0	1.1 ± 0.1	<0.1
			Stomach contents (13)	95.0 ± 6.2	1.2 ± 0.3	3.5

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[redacted]

[redacted] for the internal organs of the saury. The stomach contents, however, showed a marked increase in this ratio, as a result of higher ^{210}Po concentrations. Unfortunately, identification of their stomach contents was not possible and we therefore cannot assign this higher ratio to a particular marine entity.

The data in Table 2 suggests that, at least in the case of Pb, ^{210}Pb and ^{210}Po, evisceration of the fish prior to processing would aid in reducing the concentrations of these entities in the final [redacted] are included is not exhaustive, and clearly there are important elements missing. For example, Se and As concentrations would have been informative, as would the concentrations of Mo, Ti, Si, B and Ni. We chose the trace elements shown in Table 3 because several are considered toxic in moderate amounts (Pb, Ag, Cd, Cu) while others, in small amounts, are essential to good nutrition (Co, Fe, Zn, Mn).[12]

The high concentration of Pb in the anchovy FPC is consistent with the findings shown in

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