Thiamin, Riboflavin, and Niacin Content and Stability in Pacific Coast Seafoods

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The thiamin, riboflavin, and niacin contents of 15 species of Pacific Coast seafoods were determined to evaluate their role in the human diet. Raw white flesh finfish (ten species) were found to contain 0.05 ± 0.03 mg of thiamin/100 g, 0.06 ± 0.03 mg of riboflavin/100 g, and 2.42 ± 0.76 mg of niacin/100 g. Chinook salmon and albacore tuna had comparable thiamin and riboflavin levels but with significantly higher niacin levels per 100 g: 8.42 ± 0.94 mg and 15.75 ± 1.15 mg, respectively. The vitamins in raw Pacific shrimp and Dungeness crab were slightly lower than in white flesh finfish. Moreover, these levels were generally reduced in half during commercial processing and canning. Oysters and geoducks were found to have the highest riboflavin levels of any seafoods containing 0.23 ± 0.03 mg/100 g and 0.29 ± 0.07 mg/100 g, respectively. Niacin levels in geoducks and oysters were equivalent to those observed in white finfish, and this was also true for the thiamin level in oysters. The extremely low amount of thiamin found in geoducks (0.01 mg/100 g) suggested the presence of a thiaminase. No significant loss ($P < 0.05$) was detected in any of the three vitamins of seafoods held in frozen storage (0 °C) for 6 months. Also, no correlation was apparent between any of the three vitamin levels and the size and/or proximate composition of fish.

The need for nutrition information has increased with growing public awareness of nutrition. However, in attempting to present mean nutrient levels in nonprocessed foods, a major problem is the variation due to geographical and environmental factors. With seafoods the range in nutrient levels is believed to be further enlarged due to the many different species and physiological variations within a specie. A recent recommendation suggests the consumption of fish be increased (U.S. Senate Select Committee on Nutrition and Human Needs, 1977). A further comment in this report is that the nutrient content of all foods be made more available. This coincides with present efforts to obtain such data on seafoods of the Pacific Northwest. The annual per capita consumption of seafoods is at a record high 5.9 kg (National Marine Fisheries Service, 1977). Additional information should be made available to those individuals consuming much higher levels because of proximity to the resource or on dietary advice because of its low caloric and/or sodium levels (Gordon and Roberts, 1977). Adding to the overall increase in seafood consumption in the future might be increased nationwide availability of underutilized species, i.e., Pacific hake (*Merluccius productus*), brought about by the passage of the 200 mile limit.

Fifteen species of seafoods, some receiving secondary processing, which are consumed in the human diet, were analyzed for their thiamin, riboflavin, and niacin content. This information, while providing a more comprehensive regional survey, is also intended for use in compiling an educational nutritional label (Gordon, 1978) for seafoods along with mineral data obtained previously (Gordon and Roberts, 1977). Current and comprehensive reviews dealing with the vitamin content of seafoods are generally lacking. A large percentage of existing references primarily deal with the composition of whole fish or offal for animal and/or fish feeding. Two expanded nutrient surveys (Higashi, 1961, and Braekkan, 1962a,b) and the compilation of references on individual nutrients and species (Love, 1970) are some of the most informative. However, these along with Agriculture Handbook No. 8 (Watt and Merrill, 1963) still provide an incomplete vitamin profile at times.

As well as assessing certain vitamin levels in fresh seafoods, it was further decided to evaluate the effect of frozen storage and the relationship of fish size and proximate composition on nutrient content.

MATERIALS AND METHODS

Samples. The source and description of seafoods analyzed are outlined in Table I. Initially all samples were analyzed fresh, not longer than 48 h postharvest, after being obtained from local fishermen and/or canneries. Fish and whole raw shrimp were filleted and peeled, respectively, by hand in the laboratory. Both fillets from each fish (no. 1–10) were homogenized together in a large blender for 2 min. Random sections from filleted salmon and tuna (no. 11 and 13), totaling approximately one-third of each fish, were homogenized. Canned samples of these two species (no. 12 and 14) were thermally processed in the laboratory using 307 × 113 cans at 116 °C for 100 min. All partially cooked (no. 19), fully cooked (no. 16 and 20), and canned shrimp (no. 17 and 22) samples were obtained after being commercially processed. For shrimp samples no. 15, 16, 18, 19, 20, and 21, 1 kg of meat was used in obtaining a homogenized composite. A second Dungeness crab sample was obtained during the period of primary harvest (3/78) vs. an early season sample (no. 23; 8/77). This second sample was divided; one-half of each crab (no. 24) was analyzed raw and the other half cooked (no. 25) and then analyzed. Twelve oysters each (no. 26) from three different size groups were used in obtaining three composites. Three whole geoducks (no. 27) were individually analyzed. Duplicate determinations for each vitamin were accomplished on three composites of each seafood. A single beef sample (no. 28) was also included for comparative purposes. After the primary analysis of all fresh samples, remaining material was vacuum sealed in moisture vapor-proof packaging film and held at 0 °C for 6 months until reanalyzed.

In an attempt to estimate the extent of methodological variation during the course of this vitamin survey, a standard food commodity was selected for concurrent analysis with each set of marine products. The product chosen was the American Association of Cereal Chemists

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Table I. Summary of Samples Analyzed

no.	sample (date harvested)	species	sample description	origin of sample	no. of fish or sample size	av wt, kg	av length, cm
1	Pacific cod (8/7/77)	*Gadus macrocephalus*	fillet, raw	so. of Astoria Canyon	3	3.1 ± 0.6	65 ± 3
2	Ling cod (8/10/77)	*Ophiodon elongatus*	fillet, raw	so. of Astoria Canyon	3	3.0 ± 1.9	67 ± 14
3	Rockfish, yellowtail (8/7/77)	*Sebastodes flavidus*	fillet, raw	so. of Astoria Canyon	3	2.2 ± 0.5	53 ± 3
4	Rockfish, orange (8/10/77)	*Sebastodes pinniger*	fillet, raw	so. of Astoria Canyon	3	2.2 ± 0.5	53 ± 4
5	Rockfish, black (8/18/77)	*Sebastodes melanops*	fillet, raw	mouth of Columbia River	3	2.5 ± 0.6	53 ± 5
6	Dover sole (8/28/77)	*Microstomus pacificus*	fillet, raw	no. of Astoria Canyon	3	0.5 ± 0.1	38 ± 3
7	Butter sole (8/23/77)	*Isopsetta isolepis*	fillet, raw	no. of Astoria Canyon	3	0.6 ± 0	39 ± 1
8	English sole (8/15/77)	*Parophrys vetulus*	fillet, raw	Columbia River Bar	3	0.5 ± 0.1	38 ± 2
9	Starry flounder (8/15/77)	*Platichthys stellatus*	fillet, raw	Columbia River Bar	3	1.5 ± 0.9	49 ± 9
10	Pacific hake (8/29/77)	*Merluccius productus*	fillet, raw	north OR coast	3	1.0 ± 0.3	53 ± 4
11	Chinook salmon, raw (8/22/77)	*Oncorhynchus tshawytscha*	fillet, raw	Columbia River, gillnet	3	8.7 ± 4.1	86 ± 9[d]
12	Chinook salmon, canned (8/22/77)	*Oncorhynchus tshawytscha*	canned sample no. 11[a]	Columbia River, gillnet	3 cans		
13	Albacore tuna, raw (8/77)	*Thunnus alalunga*	white meat only	off OR Coast	3	5.9 ± 3.5	64 ± 12
14	Albacore tuna, canned (8/77)	*Thunnus alalunga*	canned sample no. 13[a]	off OR Coast	3 cans		
15	Pacific shrimp, sample I, raw (8/23/77)	*Pandalus jordani*	raw	no. of Astoria Canyon	1 kg raw shrimp	raw count 220–260/kg	
16	Pacific shrimp, sample I, cooked (8/23/77)	*Pandalus jordani*	fully processed (Model A peeler), ready to eat, sample no. 15	no. of Astoria Canyon	1 kg cooked shrimp	raw count 220–260/kg	
17	Pacific shrimp, sample I, canned (8/23/77)	*Pandalus jordani*	canned sample no. 15[b]	no. of Astoria Canyon	3 cans		
18	Pacific shrimp, sample II, raw (9/27/77)	*Pandalus jordani*	raw	off Newport, OR coast	1 kg raw shrimp	raw count 200–240/kg	
19	Pacific shrimp, sample II, partially cooked (9/27/77)	*Pandalus jordani*	partially processed (PCA peeler) sample no. 18	off Newport, OR coast	1 kg meat	raw count 200–240/kg	
20	Pacific shrimp, sample II, IQF (9/27/77)	*Pandalus jordani*	fully cooked (PCA peeler), IQF ready to eat, sample no. 18	off Newport, OR coast	1 kg meat	raw count 200–240/kg	
21	Pacific shrimp, sample III, raw (9/28/77)	*Pandalus jordani*	raw	off Crescent City, CA coast	1 kg raw shrimp	raw count 220–260/kg	
22	Pacific shrimp, sample III, canned (9/28/77)	*Pandalus jordani*	canned sample no. 21[b]	off Crescent City, CA coast	3 cans		
23	Dungeness crab, sample I, cooked (8/29/77)	*Cancer magister*	fully cooked in salt[c]	off Long Beach, WA coast	3 whole	0.9 ± 0.4	
24	Dungeness crab, sample II, raw (3/12/78)	*Cancer magister*	1/2 of crab raw	off Tillamook, OR coast	3 halves	1.0 ± 0.3	
25	Dungeness crab, sample II, cooked (3/12/78)	*Cancer magister*	1/2 of each crab (no. 24) cooked[c]	off Tillamook, OR coast	3 halves	1.0 ± 0.3	

26	Oysters (11/17/78)	*Crassostrea gigas*	whole, raw	Willapa Bay, WA	3 lots, 2 kg/lot	3 lots: 30 g, 47 g, 63 g (av wt, ea. oyster)
27	Geoduck (3/1/78)	*Panope generosa*	whole, raw	Poulsbo, WA	3	0.5 ± 0
28	Round steak (6/9/78)		lean, most visible	local abattoir		1 kg

[a] See Material and Methods section for laboratory canning procedure. [b] Commercially processed; 2.85 g of NaCl and 0.27 g of citric acid added to can. [c] Picked body and leg meat, salt added to cooking water. [d] Eviscerated.

Certified Food Grade Wheat Bran.

Proximate Analysis. Protein (total N × 6.25), ash, and moisture were determined on each sample using AOAC procedures (1975a,b,c, respectively). Lipid was measured by the method of Folch et al. (1957).

Vitamin Analysis. Individual subsamples of each homogenized composite were utilized for analysis of thiamin, riboflavin, and niacin employing the thiochrome (Pearson, 1967a), fluorometric (Pearson, 1967b), and microbiological (Goldsmith and Miller, 1967) methods, respectively. For thiamin and riboflavin, 10 g of sample were dispersed in 75 mL of 0.1 N HCl and heated at 116 °C for 15 min. To the thiamin sample was added 5 mL of 2.5 M sodium acetate containing 10% Clarase (α-amylase, *Aspergillus oxyzae*, Miles Laboratories, Inc., Elkhart, IN) and incubated for 20 h at 37 °C. The samples brought to 100 mL were filtered through Whatman No. 40 filter paper. Discarding the first filtered fraction, aliquots were passed through previously washed Thiochrome Decalso base exchange columns along with appropriate standard solutions (USP Reference Standard Thiamin Hydrochloride, U.S.P.C., Inc., Rockville, MD). Recovered thiamin was converted to thiochrome and quantitated fluorometrically in an Aminco-Bowman spectrophotofluorometer against a standard curve.

To the autoclaved riboflavin samples was added 5 mL of 2.5 M sodium acetate, diluted to 100 mL, and filtered through Whatman No. 40 filter paper. After discarding the first filtered fraction, 5-mL aliquots were sufficient for fluorometric assay of riboflavin using USP Reference Standard Riboflavin as internal standard.

For niacin determinations, 3–4 g of homogenized composites were dispersed in 100 mL of 1.0 N H_2SO_4 and heated at 116 °C for 30 min. The samples were cooled, adjusted to pH 6.8 with 1.0 N NaOH, and transferred to 1000-mL volumetric flasks. Aliquots obtained after filtering through Whatman No. 40 filter paper, discarding the first fraction through, were innoculated with *Lactobacillus plantarum* (ATCC 8014), incubated for 72 h at 37 °C and then titrated with dilute NaOH. Levels in marine products were calculated after comparison of the unknown against a standard curve prepared in a similar manner as outlined above using USP Reference Standard Niacin.

RESULTS AND DISCUSSION

Thiamin, riboflavin, and niacin levels found in seafoods of the Pacific Coast are listed in Table II. White flesh finfish of the Pacific Northwest are commonly referred to as "groundfish" or "trawl fish". The first ten samples reported fall into this category. Mean values for this group of fish are believed more beneficial in conveying nutrient content rather than categorizing each specie based on its vitamin content. The lack of previous vitamin measurements on some species makes individual comparisons impossible. Mean vitamin levels found in these groundfish were: 0.05 ± 0.03 mg of thiamin/100 g, 0.06 ± 0.03 mg of riboflavin/100 g, and 2.42 ± 0.75 mg of niacin/100 g. Only one fish deviated by more than 1 mean standard deviation for all three vitamins, that being Starry flounder (no. 9). Using the criteria of 1 mean standard deviation difference, Ling cod (no. 2) had a higher riboflavin level, Dover sole (no. 6) and Butter sole (no. 7) had lower niacin levels while Rockfish, yellowtail (No. 3) had a higher niacin level. The mean values for thiamin and riboflavin appear to agree with the amounts listed for various fish in Agriculture Handbook No. 8 (Watt and Merrill, 1963; items No. 794, 1018, 1102, 1265, and 1892). Niacin values reported in this reference on composition are incomplete and more vari-

Table II. Thiamin, Riboflavin, and Niacin Content of Pacific Coast Fish

no.	sample	thiamin, mg/100 g	riboflavin, mg/100 g	niacin, mg/100 g
1	Pacific cod[a]	0.022 ± 0.005[a]	0.042 ± 0.003[a]	2.04 ± 0.43[a]
2	Ling cod[a]	0.030 ± 0.011	0.114 ± 0.016	1.90 ± 0.31
3	Rockfish, yellowtail[a]	0.037 ± 0.006	0.076 ± 0.014	3.35 ± 0.91
4	Rockfish, orange[a]	0.044 ± 0.011	0.044 ± 0.011	2.69 ± 0.33
5	Rockfish, green[a]	0.053 ± 0.009	0.053 ± 0.009	2.85 ± 0.62
6	Dover sole[a]	0.073 ± 0.006	0.038 ± 0.003	1.60 ± 0.34
7	Butter sole[a]	0.038 ± 0.012	0.051 ± 0.005	1.17 ± 0.18
8	English sole[a]	0.043 ± 0.002	0.043 ± 0.002	2.88 ± 0.63
9	Starry flounder[a]	0.143 ± 0.046	0.114 ± 0.016	3.49 ± 0.73
10	Pacific hake[a]	0.052 ± 0.010	0.061 ± 0.008	2.19 ± 0.16
11	Chinook salmon, raw[a]	0.037 ± 0.010	0.114 ± 0.036	8.42 ± 0.94
12	Chinook salmon, canned[a]	0.012 ± 0.005	0.129 ± 0.034	7.25 ± 0.76
13	Albacore tuna, raw[a]	0.044 ± 0.009	0.045 ± 0.006	15.75 ± 1.15
14	Albacore tuna, canned[a]	0.043 ± 0.003	0.060 ± 0.003	13.43 ± 0.64
15	Pacific shrimp, sample I, raw[b]	0.028[b]	0.036[b]	1.18[b]
16	Pacific shrimp, sample I, cooked[b]	0.021	0.018	0.78
17	Pacific shrimp, sample II, canned[b]	0.013	0.014	0.74
18	Pacific shrimp, sample II, raw[b]	0.035	0.032	1.68
19	Pacific shrimp, sample II, partially cooked[b]	0.024	0.026	1.18
20	Pacific shrimp, sample II, cooked, IQF[b]	0.024	0.017	1.04
21	Pacific shrimp, sample III, raw[b]	0.040	0.034	1.77
22	Pacific shrimp, sample III, canned[b]	0.011	0.014	0.73
23	Dungeness crab, sample I, cooked[a]	0.037 ± 0.005		2.26 ± 0.07
24	Dungeness crab, sample II, raw[a]	0.047 ± 0.017	0.167 ± 0.086	3.14 ± 0.14
25	Dungeness crab, sample II, cooked[a]	0.059 ± 0.017	0.127 ± 0.059	2.43 ± 0.30
26	Oysters[a]	0.067 ± 0.012	0.233 ± 0.032	2.01 ± 0.19
27	Geoduck[a]	0.005 ± 0.001	0.290 ± 0.069	1.71 ± 0.05
28	Round steak[c]	0.094 ± 0.005	0.103 ± 0.007	4.76 ± 0.16
29	Pacific shrimp, raw[d]	0.034 ± 0.006	0.034 ± 0.004	1.58 ± 0.27
30	Pacific shrimp, cooked[e]	0.023 ± 0.002	0.020 ± 0.007	0.99 ± 0.20
31	Pacific shrimp, canned[f]	0.011 ± 0.002	0.015 ± 0.004	0.78 ± 0.03

[a] Mean ±SD, duplicate determination on three individual composite samples. [b] For all shrimp samples, value reported is mean of duplicate determinations. [c] Mean ±SD, sample no. 28 in triplicate. [d] Mean ±SD, samples no. 15, 18, and 21 in duplicate. [e] Mean ±SD, samples no. 16 and 20 in duplicate. [f] Mean ±SD samples no. 17 and 22 in duplicate.

able; i.e., the niacin content of Pacific hake is reported to be 8.3 mg/100 g vs. the 2.2 mg/100 g found in this study. In comparing the results of this study and a previous sampling for thiamin (Sautier, 1946a) and riboflavin (Sautier, 1946b), in fishery products of the Pacific Northwest, plus reviews dealing with diverse geographical samplings (Higashi, 1961; Braekkan, 1962a,b), the vitamin levels reported herein appear to be typical of what can be expected in most white flesh fish. A good estimate of the range for these three vitamins per 100 g of groundfish, again based on this study and previous observations, would appear to be 0.01–0.15 mg of thiamin, 0.03–0.16 mg of riboflavin, and 1.3–3.8 mg of niacin. The range within a specie observed here and by others (Braekkan, 1959) does not appear to vary as greatly as between species. However, the range within a specie expands when the results of different investigators are combined as would be expected. If the range between species could be documented better, efforts could be made to refer to the nutritional composition of all white fish as a collective group. With a much larger emphasis on seafoods in the diet of many foreign countries, a great deal of original literature exists that has not been translated nor referenced.

The thiamin and riboflavin levels observed in raw salmon (no. 11) are one-third and one-half lower, respectively, than reported by Sautier (1946a,b). However, vitamin levels for the same sample canned (no. 12) are in agreement with a larger survey (National Canners Association, 1950). The reduction in thiamin after canning and retorting the salmon suggests vitamin destruction. This thiamin loss was not observed in canned tuna processed in an identical manner. Higashi (1962) has stated the canning of tuna results in the loss of 70% thiamin, 15% riboflavin, and 10% niacin from the raw product. The canning of swordfish has been shown to result in a thiamin loss (Lopez-Matas and Fellers, 1947) of 75%. The extent of thiamin destruction in seafoods via canning is probably most dependent upon sample pH. Salmon and tuna, both raw and canned, have thiamin and riboflavin levels comparable to that of groundfish. The niacin content of salmon and tuna are approximately three and five times that found in groundfish. High niacin levels have been reported to be associated with higher lipid containing fish (Higashi, 1961) and those more active in feeding habits (Braekkan, 1959). Pacific shrimp samples 15, 18, and 21 were obtained from different locations with subsequent shrimp from each lot processed commercially under different conditions. The results obtained after each treatment are given (no. 16, 17, 19, 20, and 22) along with combined results in three categories: raw, cooked, and canned (no. 29, 30, and 31, respectively). From the raw product, there is about a 40% reduction in all three vitamins after cooking. This reduction is believed to be primarily due to the extensive water flume used in the peeling and cooking of shrimp. A further reduction in the level of all three vitamins is observed in the canned product. The most probable explanation to be offered in accounting for this loss is the fact the liquid is drained from the can prior to analysis of the shrimp meat on an as consumed basis. It has been reported that diffusion of water-soluble vitamins into the brine of canned seafoods can amount to 30–35% (Bramsnaes, 1962). Dungeness crab has thiamin and niacin levels comparable to groundfish while the amount of riboflavin is twice as large. Previous reports of a thiamin level of 0.18 mg/100 g (Sautier, 1946a) and a riboflavin value of 0.02 mg/100 g (Sautier, 1946b) are very much in disagreement with results of this study. Since the cooking of crab (Thurston,

Table III. Thiamin, Riboflavin, and Niacin Levels in AACC Certified Food Grade Wheat Bran

	reported,[a] mg/100 g	observed,[b] mg/100 g	within-mean coeff. of variation,[c] %	between coeff. of variation, %
thiamin	0.78	0.68 ± 0.15 (59)	2.8	22.1
riboflavin	0.39	0.32 ± 0.05 (136)	7.9	15.6
niacin	20.9	23.8 ± 3.99 (49)	1.2	16.8

[a] Average of duplicate analysis as reported for AACC Certified Food Grade Wheat Bran, (American Association of Cereal Chemists). [b] Mean ± standard deviation, number of observations performed through entire survey indicated in parentheses. [c] Mean of daily coefficients of variation on duplicate determinations.

1964) is short and large amounts of water are not used as with shrimp, the vitamin content of this food is not expected to be greatly altered by processing. Results would indicate that current tables on food composition be revised in regards to vitamin levels in crab and shrimp.

There does not appear to be any previous reference to the level of water-soluble vitamins in the geoduck (no. 27). The results obtained from geoducks and oysters suggest that mollusks are a high source of riboflavin among marine foods. This may be a geographical occurrence since East Coast oysters (*Crassostrea virginica*) were found to have only 0.18 mg of riboflavin/100 g (Wentworth and Lewis, 1958). The low thiamin level in geoducks would suggest the presence of thiaminase, but this has not been documented (Goldbeck, 1947; Greig and Gnaldinger, 1971). Red meat (No. 28) contains approximately twice as much thiamin, riboflavin, and niacin as the groundfish samples tested.

In attempting to accomplish a nutrient survey of different foods and especially for some not previously evaluated, the question develops as to the accuracy of the data for present and future comparisons. While common techniques for vitamin determinations have been employed against daily standards, these methods have not received the degree of scrutiny with seafoods as they have with other foods, i.e., fruits and vegetables (AOAC procedures 1975d,e,f). It would be ideal to have a certified reference food standard for vitamins as now available for most minerals through the National Bureau of Standards. Having reference material would give some idea of the variation due to methodology so often mentioned as causing conflicts in nutrient surveys. To best accomplish this conceived criteria during the course of this survey, Certified Food Grade Wheat Bran was run in duplicate along with marine samples daily. This bran was not certified as to its vitamin content, but its thiamin, riboflavin, and niacin levels were reported and these levels were not expected to change significantly over the length of this study (Zeleny, 1973). Table III indicates the mean and standard deviation found for these three vitamins in bran over 10 months (8/77–5/78). The variation between days was random. From this information it is believed that the mean vitamin values reported for seafoods could vary at least by the coefficient of variation observed in wheat bran above or below the levels observed and reported in Table II. This would tend to enlarge the range of vitamin levels within a specie in this study, but not necessarily change

Table IV. Recovery of Thiamin, Riboflavin, and Niacin Standards Added to Fish Samples[a]

	thiamin				riboflavin				niacin			
sample no.	added thiamin, μg	sample wt, g	obsd μg/g[b]	% recov.[c]	added riboflavin, μg	sample wt, g	obsd μg/g[d]	% recov.[c]	added niacin, μg	sample wt, g	obsd μg/g[d]	% recov.[c]
1	0	11.80	0.41		0	12.15	0.70		0	5.10	26.9	
2	0	9.55	0.44		0	8.55	0.81		0	4.55	27.3	
3	0.5	10.80	0.45	94.5	1	11.20	0.84	100.0	20	3.90	32.3	100.3
4	0.5	11.30	0.47	99.2	1	11.45	0.74	88.1	20	3.90	32.3	100.3
5	1.0	10.65	0.51	95.5	2	11.00	0.96	103.0	40	3.85	36.4	97.1
6	1.0	10.75	0.50	93.8	2	10.00	0.95	100.0	40	3.55	36.9	96.1
7	2.0	8.90	0.63	96.2	4	12.60	1.18	110.6	80	4.35	42.0	108.3
8	2.0	11.20	0.59	96.9	4	10.80	1.02	91.1	80	3.30	45.3	112.8
mean % recovery				96.0				98.7				102.5
value by method of addition[e]			0.42				0.72				28.9	

[a] Subsamples of one composite fish, Rockfish green, sample no. 5. [b] Single observation. [c] Percent recovery based on observed level/g divided by mean level observed in samples 1 and 2 plus added level/g. [d] Mean of duplicate observations. [e] Intercept of equation $y = mx + b$; y = observed μg/g, x = added μg/g.

Table V. Comparison of Physical Characteristics and Proximate Composition on Vitamin Levels in Selected Seafoods

sample	sample no.	wt, kg	length, cm	protein, %	lipid, %	thiamin, mg/100 g	riboflavin, mg/100 g	niacin, mg/100 g
Ling cod	2-1	1.15	20.5	18.77	0.93	0.026	0.041	1.86
	2-2	2.85	27.5	17.00	0.89	0.021	0.045	1.63
	2-3	4.85	31	19.28	1.12	0.021	0.041	2.20
Starry flounder	9-1	0.70	16	16.15		0.138	0.125	3.09
	9-2	1.35	19	17.84	1.21	0.109	0.108	3.81
	9-3	2.55	23	17.81	1.08	0.220	0.111	3.58
Chinook salmon, raw	11-1	4.35	30	20.70	5.52	0.038	0.085	9.39
	11-2	9.10	35	19.21	7.76	0.037	0.143	7.39
	11-3	12.50	37	20.61	14.79	0.037	0.114	8.47
Albacore tuna, raw	13-1	2.80	21	24.34	1.57	0.040	0.041	17.12
	13-2	5.15	24	24.83	8.31	0.056	0.045	15.36
	13-3	9.60	30	22.72	12.91	0.037	0.050	14.77

Table VI. Effect of Frozen Storage on the Thiamin, Riboflavin, and Niacin Content of Seafoods

		thiamin, mg/100 g[a]		riboflavin, mg/100 g[a]		niacin, mg/100 g[a]	
no.	sample	fresh	frozen	fresh	frozen	fresh	frozen
1	Pacific cod	0.021	0.044	0.045	0.048	2.21	2.07
2	Ling cod	0.042	0.042	0.114	0.098	2.24	2.15
3	Rockfish, yellowtail	0.043	0.088	0.061	0.067	2.69	2.24
4	Rockfish, orange	0.053	0.051	0.066	0.084	2.55	2.18
5	Rockfish, green	0.043	0.058	0.075	0.075	2.71	2.88
9	Starry flounder			0.108	0.098	3.07	2.56
10	Pacific hake	0.052	0.065	0.061	0.073	2.19	2.33
11	Chinook salmon, raw	0.038	0.041	0.085	0.041	9.39	8.53
12	Chinook salmon, canned	0.015 ± 0.006[b]	0.011 ± 0.003[b]	0.134 ± 0.029[b]	0.131 ± 0.025[b]	7.83 ± 0.29[b]	7.43 ± 0.47[b]
13	Albacore tuna, raw	0.037	0.032	0.045	0.058	14.76	16.39
15	Pacific shrimp, I, raw	0.028	0.039	0.036	0.026	1.18	1.66
16	Pacific shrimp, I, cooked	0.021	0.033	0.018	0.013	0.78	1.16
17	Pacific shrimp, I, canned	0.014	0.011	0.013	0.014		
21	Pacific shrimp, III, raw	0.040	0.045	0.034	0.031	1.77	1.70
22	Pacific shrimp, III, canned	0.009	0.010	0.020	0.020	0.72	0.70
26	Oysters	0.069	0.043	0.202	0.302	2.02	2.01
	$P < 0.05$		N.S.[c]		N.S.[c]		N.S.[c]

[a] Mean value of duplicate determinations on one sample. [b] Mean ±SD of four samples in duplicate. [c] No sifnificant difference between fresh and frozen sample vitamin levels as determined by Student's t test.

Table VII. Proximate Composition of Pacific Coast Fish

		percent				
no.	sample	moisture[a]	protein[a]	lipid[a]	ash[a]	carbohydrate[b]
1	Pacific cod	81.28 ± 0.29	18.70 ± 0.67	0.54 ± 0.01	1.14 ± 0.05	
2	Ling cod	79.18 ± 1.01	18.35 ± 1.20	0.98 ± 0.12	1.16 ± 0.01	
3	Rockfish, yellowtail	77.54 ± 1.02	18.78 ± 1.35	3.58 ± 0.13	1.17 ± 0.03	
4	Rockfish, orange	79.55 ± 0.78	18.88 ± 0.42	2.05 ± 0.08	1.10 ± 0.04	
5	Rockfish, green	76.42 ± 1.62	19.15 ± 0.26	3.88 ± 0.16	1.13 ± 0.04	
6	Dover sole	82.80 ± 0.16	16.81 ± 0.69	0.3[c]	0.93 ± 0.05	
7	Butter sole	80.03 ± 0.18	19.40 ± 0.94	0.4[c]	0.99 ± 0.02	
8	English sole	82.74 ± 0.51	15.48 ± 0.69	1.6[c]	0.96 ± 0.17	
9	Starry flounder	80.91[d]	17.83[d]	1.15[d]	1.13[d]	
10	Pacific hake	80.23[e]	16.87[e]	2.61[e]	1.09[e]	
11	Chinook salmon, raw[f]	70.77 ± 2.92	20.17 ± 0.84	9.42 ± 4.95	1.31 ± 0.24	
12	Chinook salmon, canned	[g]	[g]	[g]	[g]	
13	Albacore tuna, raw[f]	64.26 ± 4.59	23.96 ± 1.10	7.60 ± 5.11	1.49 ± 0.47	2.61
14	Albacore tuna, canned	67.62 ± 0.16	23.97 ± 0.86	7.97 ± 5.70	1.44 ± 0.37	
15	Pacific shrimp, sample I, raw[d]	80.53	16.88	1.51	1.24	
16	Pacific shrimp, sample I, cooked[d]	77.76	19.67	1.71	0.63	
17	Pacific shrimp, sample I, canned[d]	77.36	21.35	1.85	1.60	
18	Pacific shrimp, sample II, raw[d]	79.18	18.36	1.52	1.14	
19	Pacific shrimp, sample II, partially cooked[d]	77.98	21.32	1.59	0.94	
20	Pacific shrimp, sample II, cooked, IQF[d]	76.42	21.55	1.67	2.12	
21	Pacific shrimp, sample III, raw[d]	80.14	17.45	1.05	1.25	
22	Pacific shrimp, sample III, canned[d]	77.03	21.25	2.13	2.07	
23	Dungeness crab, sample I, cooked	77.78 ± 0.75	21.58 ± 0.48		1.71 ± 0.17	
24	Dungeness crab, sample II, raw	[g]	[g]	[g]	[g]	
25	Dungeness crab, sample II, cooked	[g]	[g]	[g]	[g]	
26	Oysters	83.36 ± 0.59	7.76 ± 0.29	2.85 ± 0.08	1.26 ± 0.05	4.8
27	Geoduck	77.33 ± 1.82	15.56 ± 0.71	1.95 ± 0.54	1.22 ± 0.06	3.9
28	Round steak	72.30 ± 0.19	21.38 ± 0.54	5.89 ± 0.21	1.01 ± 0.02	

[a] Mean ±SD, $n = 3$ individual fish or samples unless otherwise indicated. [b] By difference. [c] Lipid level estimated by difference assuming sum of components without any carbohydrate is 100.8% in finfish. [d] $n = 2$. [e] Mean SD of a three fish composite sample analyzed in triplicate. [f] Extreme variation in proximate composition of individual fish. [g] Not determined.

previous estimates observed in reviewing the literature. The variation between days is much larger when comparing it against the smaller mean coefficient of variation seen in the daily (within) analyses (Table III). This discounts the suggestion of having a nonhomogenous sample. For each vitamin, the variation between duplicate daily seafood samples was even smaller than observed for the wheat bran.

No attempt was made to adjust nutrient levels observed (Table II) by the ratio of daily to mean bran vitamin levels.

The recovery of added thiamin, riboflavin, and niacin from one fish sample (Table IV) indicates that for at least one specie there is not any interference or vitamin loss during sample preparation, extraction, or determination. There was the possibility that the extraction procedures employed with seafoods were incomplete for the conversion of riboflavin mononucleotide (FMN) and riboflavin dinucleotide (FAD) to free riboflavin. However, the quantitative extraction of flavins via HCl digestion and their conversion for total riboflavin analysis has been verified (Gordon, 1978).

Another difficulty in attempting to evaluate the best mean level of any vitamin in seafoods is the possible variation in fish in respect to physical size and proximate

composition. To evaluate this criteria, size and proximate composition of each sample for each specie was evaluated against each of the three vitamin levels found. The total lack of correlation is best illustrated in Table V where the greatest variation in physical characteristics was observed in four species. Braekkan (1959) found a similar lack of correlation between the level of the four vitamins, niacin, pantothenic acid, riboflavin, and vitamin B_{12}, in the skeletal muscle of 19 cod fish (*Gadus morrhua*) ranging in size from 0.5 to 7.7 kg. It would appear that age and composition of a fish have no bearing on its nutrient content per unit mass. Therefore, the determination of any fish within a specie would suffice to give basic information for comparative purposes. The lack of correlation is somewhat surprising when looking at the niacin levels in salmon and tuna. Fatty fish are associated with higher niacin levels (Higashi, 1961), which was observed. However, it appears the specie itself has a high niacin level irrespective of its lipid content. The lack of a large variation in the vitamin content of seafoods observed here might be the fact that only samples from one geographical region were evaluated. One review (Tarr, 1973) suggests there may be a difference in certain vitamin levels between Pacific and Atlantic Coast fish, and further, cod fish from northern areas may contain more thiamin and riboflavin than from warmer waters (Higashi, 1961). A survey of seafoods common to the New England area (Teeri et al., 1957) indicate lower niacin and riboflavin values than reported herein.

Since much of the fish today is frozen prior to consumption, a number of individual composites analyzed fresh were stored for 6 months at 0 °C and then reanalyzed. Results of one composite analyzed in duplicate before and after frozen storage are shown in Table VI. The high variation observed between some samples is only believed due to methodology, again pointing up the value of an internal standard. In evaluating all samples as a fresh versus a frozen group, there was no decrease ($P < 0.05$) in any of the three vitamins with frozen storage.

Completing the nutrient profile of Pacific Coast seafoods in their proximate composition listed in Table VII. The mean protein, lipid, and ash contents of groundfish reported here are 18.0, 1.7, and 1.1%, respectively, vs. levels of 17.0, 1.4, and 1.1% observed in a mineral survey of similar species in the same laboratory (Gordon and Roberts, 1977). The proximate composition of Pacific Coast groundfish have been extensively evaluated (Thurston, 1961a,b,c; Stansby, 1976). There are only two items to warrant comment. In adding the sum of components of raw tuna (no. 13), a net difference resulted in an entry for carbohydrate. This was found in repeated proximate determinations of raw tuna but not canned (no. 14). The second item of interest is the high protein (N × 6.25) content of geoduck. Other mollusks having such high protein levels (Sidwell et al., 1973) include surf clam (*Spisula solidissima*) and scallops (all species).

In conclusion, the evolution of the thiamin, riboflavin, and niacin contents of Pacific Coast seafoods has placed the nutrient contribution of these food items in proper perspective. For groundfish, one serving, 100 g, provides 3.6, 3.7, and 11% of the Recommended Dietary Allowances (RDA) for thiamin, riboflavin, and niacin, respectively, for the adult male. The vitamin contribution to the diet of the adult male from fish can be placed in proper perspective by considering that this same sample of fish will only provide 2.9% of the daily 3000 calorie energy requirement (Recommended Dietary Allowances, 1974). It has been shown that size and proximate composition have little effect on nutrient composition. The extent of geographical location is not believed to alter the range in vitamin levels, but this along with seasonal variation has not been adequately determined.

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Determination of Chromium in Selected United States Diets

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As a basis for estimating mean daily chromium intake in the United States, chromium contents of 28 selected daily diets of different compositions were determined by graphite furnace atomic absorption utilizing a continuum source, echelle, wavelength modulated atomic absorption spectrometer system for improved background correction. These diets were prepared for a human metabolic study of high fat (43%) and low fat (25%) content diets at the Nutrition Institute, Beltsville, MD. The 43% fat diets which were "typical American diets" with regard to fat and calories contained less chromium (62 ± 28 μg/day) than the 25% fat diets (89 ± 56 μg/day). Fifty-seven percent (8/14) of the high fat and 21% (3/14) of the low fat diets were at or below the minimum of the recently proposed range of chromium intake of 50–200 μg/day.

Recent studies in research on chromium nutrition have confirmed earlier findings with experimental animals which suggested that chromium was essential for the normal glucose tolerance of man (Mertz, 1969; Hopkins et al., 1971; Jeejeebhoy et al., 1977; Mertz et al., 1978; Glinsmann et al., 1966). As a result, a provisional recommendation for chromium intake has been proposed for the next revision of the Recommended Dietary Allowances (RDA) (Mertz, 1979).

In order to determine whether or not the chromium intake of people will meet the recommended level, we need reliable data on the level of chromium supplied by diets of different compositions. Only scattered information is available on the daily chromium intake in the United States. Levine et al. (1968) analyzed seven diets, of elderly and of young subjects eating institutional diets, and found that the daily chromium intake varied from 5 to 115 μg. Mean daily chromium intake was 52 μg for elderly subjects and 65 μg for young subjects. Schroeder et al. (1962) found 70 μg/day chromium intake in a typical institutional diet. These values are lower than the reported average daily chromium intake in Japan, which was determined as 130–140 μg (Murakami et al., 1965). In West Germany, Schelenz (1977) recently estimated the dietary intake of 25 elements, including chromium, based on analyses of the total daily diet of four adult males during 1 week. Intake of chromium averaged 62 μg/day, ranging from 11 to 195 μg/day. The analytical validity of these data is, however, difficult to evaluate because suitable Standard Reference Materials (SRM) for chromium were not available at the time of these analyses. Only recently has the National Bureau of Standards (NBS) issued the chromium certified brewer's yeast (SRM-1569) and also certified the previously issued bovine liver (SRM-1577) for chromium. Orchard leaves (SRM-1571) had been certified for Cr, but as a plant material it contains high levels of Cr in a different form. Several additional chromium certified plant material SRM are now available from NBS including spinach (SRM-1570), pine needles (SRM-1575), and tomato leaves (SRM-1573).

Several laboratory comparison studies indicate that the present state of chromium analysis in biological and environmental materials is not yet satisfactory (Mertz et al., 1977; McClendon, 1974; Parr, 1978; Kumpulainen and Koivistoinen, 1977; Schelenz, 1977; Scott, 1978). For analysis of chromium in a water matrix, graphite furnace atomic absorption spectrophotometry is relatively reliable, sensitive, and rapid. However, for the analysis of complex matrices such as food, errors are apparently introduced during the digestion of organic matter and other steps in the preparation of samples for the instrumental analysis. In wet digestion, large amounts of acids may be a significant source of chromium contamination even when reagents of the highest attainable purity are used.

There is also some evidence that chromium may form volatile compounds during some wet digestions, especially if the mixture contains perchloric acid (Gorsuch, 1959; McClendon, 1978). Chromium may be lost by volatilization during dry ashing at temperatures of 700 °C or higher (Shapcott et al., 1977; Koirtyohann and Hopkins, 1976). Results may also be erratic due to adsorption of Cr on the walls of crucibles during dry ashing (Koirtyohann and Hopkins, 1976; Shapcot et al., 1977; Jones et al., 1975). Low-temperature ashing would eliminate most of these problems, but we found that it was ineffective for the digestion of bovine liver (SRM-1577). Furthermore, in low-temperature ashing, the sample size is more limited than in dry ashing and use of relatively high amounts of hydrogen peroxide are often needed as an ashing aid.

Some biological materials such as brewer's yeast (SRM-1569), contain acid-insoluble material, apparently silicates, that can strongly adsorb chromium. Therefore,

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