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COMPOSITION OF FISH

By M. E. Stansby, Chemist in Charge
Seattle Technological Laboratory, U. S. Fish & Wildlife Service

1. Variation in Composition

Before considering the chemical composition of fish, it should be realized that there is a considerable variation in such composition, so that analyses made on only a few samples cannot be considered representative, and, in fact, in many cases variation is so great that average composition is of only theoretical interest since actually individual fish will vary so widely from such average values.

Doubtlessly the component of fish varying to the greatest degree is the oil (or fat) content. Many species of fish store oil when feeding as a reserve to draw upon later. Such fish generally migrate over vast distances and during the migration may not feed upon anything except their stored oil reserve. This causes a seasonal variation in oil content as shown in Table 1. The oil content of mackerel may vary by as much as eleven times, and even in a single lot of fish caught together it may vary by as much as seven times. In addition to season of the year, other factors which may cause variation of oil content of fish include nature of food of fish, locality where fish are caught, and size and age of mackerel. The smaller fish show less variation of oil content than do the large fish (Table 2).

TABLE 1.--Seasonal variation of oil content of Mackerel (Scomber scombrus)[a]

Date fish were caught	Number of fish analyzed	Maximum oil content	Minimum oil content	Average oil content
		Percent	Percent	Percent
April 18	13[b]	..	..	3.9
April 22	8	7.6	2.7	4.8
May 3	4[b]	..	..	8.0
May 21	4[b]	..	..	9.0
June 1	6[b]	..	..	9.8
July 23	13	17.3	6.1	10.6
August 13	7	25.6	10.6	17.5
August 15	7	21.6	16.0	19.2
September 11	20	11.4	2.0	6.5
October 1	25	16.2	3.0	10.1
Nov. 17	12	15.2	2.2	8.2

a/ M. E. Stansby and J. M. Lemon, U. S. Fish and Wildlife Service, Research Report No. 1

b/ Composite samples

TABLE 2.--Effect of size of Mackerel on oil content[a]

Length of fish	Probable age group	Average oil content		
		June 5	Oct. 20	Nov. 17
c.m.	Years	Percent	Percent	Percent
30--31.5	1	...	14.6	9.4
31.5--36.5	2	9.3	13.6	22.0
36.5--38	3	7.0	16.5	20.1
39--42	5 and 6	4.0	17.1	16.5
41--44	7 and over	2.2	....	....

While the oil content of fish varies more widely than other components, most of the other substances present show some variation. The water content of many species varies inversely with the oil content such that on the edible portions of the flesh, the sum of the water and oil content is usually quite close to a constant value.

Fish also vary in composition at different sections of the same fish as shown in Table 3. The oil content is generally lower near the tail than near the head. This is an important consideration for purchasers of fish, since those desiring a lean fish should procure tail cuts while those preferring fish to be quite oily can specify cuts from near the head.

TABLE 3.--Variation in Composition of different portions of the same fish[b]

Species	Cross section analyzed	Fat	Protein	Ash
		Percent	Percent	Percent
Salmon (red chinook)	Near head	20.2	17.6	1.19
Salmon (red chinook)	Near tail	11.1	17.9	1.12
Salmon (white chinook)	Near head	15.1	19.0	1.40
Salmon (white chinook)	Near tail	8.1	19.9	1.31
Yellowtail	Middle	3.21	19.8	1.35
Yellowtail	Near tail	1.38	21.0	1.35
Skipjack	Belly only	25.8	18.3	1.35
Skipjack	White meat only	15.4	21.9	1.39
Skipjack	Dark meat only	22.4	18.2	1.03

a/ M. E. Stansby and J. M. Lemon, U. S. Fish and Wildlife Service, Research Report No. 1

b/ H. Beard (editor), Rept. U. S. Commissioner of Fisheries for 1925 (1926), Appendix 10, p. 501.

2. Gross Composition

Tables of average gross composition of fish are apt to be misleading as stated in the previous section but if their limitations are realized they may be useful to obtain an approximation of the composition of the various species.

No comprehensive analyses of gross composition of fish have been made since the very exhaustive studies of Atwater (1892)1/. Although these analyses were made more than 50 years ago the methods of analysis for the most part are beyond reproach. Unfortunately proper consideration was not given to seasonal variation in composition which greatly limits the value of this report. Table 4 summarizes the best available data on oil and protein content of fish. In most instances it has been necessary to use data of Atwater, but whenever more recent, reliable data have been available, they have been included. The older tables generally give analyses on other components such as ash, water, and various nitrogen fractions such as coagulable, hot water soluble, etc. The ash content averages about 1.3% for all species. It is reasonably constant between about 1.0 and 1.5% and its variation has no especial significance. Inasmuch as the water content has no nutritional significance, its inclusion likewise seems unnecessary.

3. Protein Content

The mere statement of protein content of fish (generally computed by multiplying the nitrogen content by a factor) as given in Table 4 gives very little information as to the relative nutritive value of the fish. Thus in the dogfish, much of the nitrogen occurs as urea so that the protein content, calculated from nitrogen analyses, is quite erroneous. Even assuming the protein content to be accurate, as determined, a more precise knowledge of the composition of the protein is necessary before any decision as to the relative nutritive value can be made. Table 5 gives analyses for arginine, histidine, lysine, tryptophane, and cystine on certain species of fish. The last four of these five amino acids have been found to be essential to growth. For comparison, analyses on certain other proteins have been included. The analyses of fish and shellfish for these five amino acids compare very favorably with the analyses for casein (principal protein in milk), beef round, and egg albumin.

1/ Publications referred to parenthetically by date are listed in the Literature Cited, pp. 16-18.

TABLE 4. -- Oil and protein content of the edible portion of fish

Species	Average oil content	Protein content
	Percent	Percent
Fish:		
Alewives	5	19
Cod	0.4	17
Croaker	3	18
Flounder	0.6	16
Haddock	0.3	18
Halibut	5	19
Herring, sea	11	19
Mackerel, common	13	18
Mullet	5	19
Pollock	0.8	20
Salmon, king[a]	16	18
Salmon, sockeye [a]	11	21
Salmon, coho[a]	8	21
Salmon, pink[a]	6	21
Salmon, chum[a]	5	21
Sardine (pilchard)	13	23
Squeteague (sea trout)	2	19
Tuna, skipjack[a]	4	22
Whiting	0.4	17
Shellfish:		
Clams	1	9
Crabs	2	17
Oysters	1	7
Shrimp	1	25

a/ canned

TABLE 5.--Percentage of certain essential amino acids in fish and shellfish[a]

Species	Scientific Name	Date sample was prepared Date	Arginine Percent	Histidine Percent	Lysine Percent	Tryptophane Percent	Cystine Percent
Fish:							
Catfish	Ameiurus catus	Aug., 1937	....	....	....	0.97	...
Cod	Gadus callarias	June, 1936	5.58	1.72	6.83	1.06	1.41
Croaker	Micropogon undulalus	May, 1936	5.81	1.37	6.10	1.24	1.15
Haddock	Melanogrammus aeglefinus	Sept., 1935	5.70	1.17	6.41	0.85	1.16
Halibut	Hippoglossus hippoglossus	Dec., 1936	6.00	1.66	6.16	1.64	1.45
Herring:							
Lake	Leucichthys artedi	Nov., 1937	....	....	....	1.25	....
Sea	Clupea harengus	March, 1937	5.09	1.56	7.03	1.23	....
Lake trout	Cristivomer namaycush	June, 1937	5.73	1.40	7.15	1.17	....
Mackerel:							
Boston	Scomber scombrus	Aug., 1936	5.78	1.93	7.13	1.36	1.18
Spanish	Scomberomorus maculatus	Jan., 1936	5.27	1.48	6.53	1.37	1.25
Mullet	Mugil species	Feb., 1937	5.78	1.61	6.74	1.36	1.29
Pilchard	Sardina caerulea	March, 1937	5.60	1.23	6.78	1.30	....
Red Snapper	Lutianus blackfordii	Nov., 1936	6.18	1.57	6.72	1.22	1.29
Salmon:							
Chum	Oncorhynchus keta	May, 1938	5.55	1.30	5.69	1.33	....
King	Oncorhynchus tachawytscha	April, 1937	5.02	1.41	6.27	1.20	1.27
Pink	Oncorhynchus gorbuscha	April, 1937	....	....	....	1.09	1.15
Silver	Oncorhynchus kisutch	Jan., 1937	5.68	1.87	6.57	1.44	1.39
Sockeye	Oncorhynchus nerka	Sept., 1937	....	....	....	1.25	....
Shad	Alosa sapidissima	May, 1936	4.54	1.09	6.45	1.22	1.17
Squeteague (sea trout)	Cynoscion regalis	June, 1937	5.90	1.42	6.78	1.01	....
Tuna:							
Albacore	Germo alalunga	Nov., 1937	....	....	....	1.18	....
Bluefin	Thunnus saliens	Oct., 1937	....	....	....	1.25	....
Bonito	Sarda chilensis	Sept., 1937	....	....	....	1.19	....
Skipjack	Euthynnus pelayms	Dec., 1937	....	....	....	1.16	....
Shellfish and crustacea:							
Clam, hard	Venus mercenaria	Sept., 1936	5.27	1.45	5.40	1.19	....
Crab, blue	Callinectes sapidus	Nov., 1936	7.61	1.51	6.38	1.11	....
Oyster	Ostrea virginica	Oct., 1936	5.71	1.79	5.24	1.67	....
Shrimp	Peneus brasiliensis	June, 1936	7.50	1.61	7.35	0.96	1.25
Proteins from other foods:							
Casein	.....	....	5.2	2.6	7.6	2.2	0.3
Beef round	.....	....	7.5	1.8	7.6	0.9	1.3
Egg albumin	.....	....	6.0	2.3	3.8	1.3	0.9

a/ S. R. Pottinger and W. H. Baldwin, Proc. Pacific Sci. Congr. 6th Congr., Calif. (1939), p. 453.

4. Mineral Content

Newell and McCollum (1931) made a semiquantitative spectrographic analysis of certain fish meals and found relatively large amounts of calcium, copper, iron, magnesium, phosphorus, potassium, sodium, and strontium to be present. Smaller amounts of aluminum, fluorine, lithium, and manganese were present, and small traces of barium, chromium, lead, silicon, titanium, vanadium, and zinc were found in most samples. A few samples were found to contain small traces of boron, nickel, niobium, silver, and tin. While some of these elements may represent contaminants picked up during manufacture of the fish meal, it appears probable that most of them were present initially in the fish from which the meal was prepared. In addition to these elements chlorine and sulfur are always found in relatively large quantities, as well as smaller traces of bromine and iodine.

Table 6 gives analyses for certain mineral constituents of nutritional importance in a number of species. Of the elements listed, iodine, although occurring in the smallest quantities, is the most important. This element, so essential in the prevention of goiter, is more abundant in sea foods than in any other natural foodstuff. Oysters are also a very excellent source of iron and copper, being exceeded in content of these minerals only by pork liver and beef liver. Canned salmon, owing to the presence of the softened, edible bone, is an important source of calcium, being exceeded only by cheese and certain nuts in this respect. Other canned fish in which the bone is not removed are equally good sources of calcium.

Fish contain considerably higher quantities of fluorine than do most foodstuffs, averaging about 5 p. p. m. according to Lee and Nilson (1939). This compares with 0.5 to 2.0 p. p. m. of fluorine in most other common foods. Since fluorine in excess of 2 p. p. m. in drinking water will cause mottled teeth, and since the U. S. Food and Drug Administration prohibits added fluorine in foods in excess of 1.4 p. p. m., it might appear that the presence of 5 p. p. m. in sea foods would have a harmful effect. Lee and Nilson (1939) have shown that this is not the case, however. Apparently the fluorine is present in some form such that assimilation is much less than is the case with added inorganic fluorides. Similarly, Coulson, Remington, and Lynch (1934) have shown that the relatively high copper content of oysters has no harmful effect, and that there is no rapid accumulation of copper in the body when large quantities of oysters are consumed.

Arsenic has also been reported by Chapman (1926) to occur in sea foods in quantities higher than in most other foods. Analyses showed arsenic to be present in various species expressed as parts per million as follows:

British oysters, 5; Portuguese oysters, 50; mussels, 82; lobster, 37; shrimp, 24; crabs, 46; crawfish, 32; sole, 7. Coulson, Remington, and Lynch (1935) have shown that the arsenic present in shrimp is organically combined in a form not readily absorbed during metabolism.

TABLE 6.--The mineral content of the edible portion of certain fish[a/]

Species	Number of samples	Dry matter[b/]	Calcium	Magnesium	Phosphorus	Iron	Copper	Iodine
		Percent	Percent	Percent	Percent	Percent	Percent	Percent
Fish:								
Cod (Gadus morrhua)	4	17.7	0.0110	0.0280	0.1859	0.000518	0.000041	0.000103
Haddock (Melanogrammus aeglefinus	4	18.7	0.0165	0.0236	0.1731	0.000516	0.000041	0.000513
Mackerel (Scomber scombrus	2	19.9	0.0048	0.0281	0.2169	0.001224	0.000115	0.000053
Red snapper (Lutianus blackfordii	3	21.7	0.0162	0.0276	0.2279	0.001158	0.000038	0.000031
Mullet (Mugil cephalus)	3	23.9	0.0261	0.0318	0.2198	0.001779	0.000082	0.000485
Pilchard, California (sardinia caerulea)[c/]	2	20.5	0.0422	0.0237	0.2115	0.002483	0.000166	0.000013
Flounder (Pleuronectidae species)	2	21.3	0.0117	0.0305	0.2053	....	....	0.000029
Lake herring (Leuichthys artedi)	1	17.9	0.0116	0.0172	0.1518	....	....	....
Salmon, canned, red (Oncorhynchus nerka)	3	31.3	0.2082	0.0292	0.3364	0.001180	0.000081	0.000053
Salmon canned, chinook (Oncorhynchus tschawytscha)	3	33.2	0.1071	0.0267	0.2778	0.001270	0.000077	0.000067
Salmon, canned, coho (Oncorhynchus kisutch)	2	30.1	0.2304	0.0298	0.3382	0.000890	0.000064	0.000023
Salmon, canned, pink (Oncorhynchus gorbuscha)	2	29.6	0.1735	0.0299	0.3206	0.000760	0.000056	0.000021
Salmon, canned, chum (Oncorhynchus keta)	2	27.3	0.2492	0.0299	0.3518	0.000740	0.000050	0.000022
Shellfish:								
Oysters, Eastern (Ostrea virginica)	4	15.0	0.0579	0.0320	0.1121	0.006100	0.003730	0.000049
Oysters, Pacific natives (Ostrea lurida)	2	17.9	0.0632	0.0242	0.1540	0.004940	0.001240	0.000030
Oysters, Pacific, Japanese (Ostrea gigas)	2	21.4	0.0628	0.048	0.1922	0.007510	0.001230	0.000036
Shrimp (Peneus brasiliensis)								
Raw	4	20.0	0.0542	0.0421	0.2285	0.002188	0.000331	0.000023
Boiled	2	28.7	0.0614	0.0509	0.2432	0.003973	0.000302	0.000021
Blue crab (Callinectes sapidus)								
White meat	4	21.1	0.1028	0.0336	0.2052	0.002262	0.001582	0.000042
Claw meat	3	20.4	0.0706	0.0345	0.1796	0.000746	0.000368	0.000015

a/ H. W. Nilson and E. J. Coulson, U. S. Bur. Fisheries, Investigational Rept. 41 (1939).
b/ Samples first dried on steam bath and finished in electric air over at 80° C. c/ Whole fresh fish.
Note: Four units to right of decimal point equals parts per million or mg. per kg.

5. Composition of Fish Oils

The components of fish oils have been classified by Brocklesby (1941) as follows:

Group A:
- Fatty acid esters of glycerol
  - sterols
  - glycerol ethers
  - phospholipids
  - vitamins
  - pigments

Group B:
- Waxes (fatty acids esters of fatty alcohols)
- Pigments
- Dissolved nitrogenous matter

Group C:
- Hydrocarbons (including some pigments)
- Fatty alcohols

The principal component of most fish oils is the first one in this classification, namely, glycarides of fatty acids, and in true fish oils the glycerides usually make up at least 95% of the oil. The fatty acid components consist of straight-chain even-numbered 14 to 24 carbon acids with the carboxyl group at one end. The degree of unsaturation of the fatty acids increases with the number of carbon atoms. This degree of unsaturation is usually not greater than -4H for acids up to 18 carbon atoms but may be as high as -10H or more for the C_{20}, C_{22}, and C_{24} acids.

The saturated fatty acids in fish (Teleostomi) oils make up between about 10 and 25% of the total fatty acids present, and the principal acid present is palmitic. Myristic acid is the second most important of the saturated acids, and only traces of stearic acid occur in most species.

Of the unsaturated acids present in Teleostomi fish oils, only traces of C_{14} acids occur. Of the C_{16} acids palmitoleic acid is the principal one with small amounts of C_{16} acids of higher degree of unsaturation. Oleic acid is the principal component of the C_{18} unsaturated acids with smaller amounts of linolenic and moroctic acids present in some cases. C_{20} acids average 22.5% of the total unsaturated acids and C_{22} acids about 13%.

There seems to be little difference in composition between marine liver oils as a class and marine body oils. There is a slightly higher amount of saturated acids in the body oils, but the difference is not pronounced. Composition of the unsaturated acids shows no decided difference for these classes of oils.

Cholesterol is the principal sterol present in fish oils. It occurs in quite large amounts in some species. Lecithin is the principal phospholipid found in marine oils. It is present in especially high quantities (up to 20%) in oil from fish eggs, and also in various shark and dogfish liver oils. The amount present in most whole fish averages less than 0.5%. Three glycerol ethers, chymyl alcohol (glycerol α-ether of cetyl alcohol), batyl alcohol (glycerol α-ether of octadecyl alcohol), and selachyl alcohol (glycerol α-ether of mono-unsaturated oleyl alcohol), are present in relatively large quantities in ratfish-liver oil. Waxes and fatty alcohols occur principally in the head oils of certain marine mammals such as whales. The principal hydrocarbon in marine oils is squalene ($C_{30}H_{50}$) containing six unsaturated bonds. It is an important component of various fish oils, especially some species of shark-and dogfish-liver oils where it may represent one-third or more of the whole oil.

6. Vitamin Content

Fish-liver oils represent the best commercial source of vitamin A and some species, especially the tuna fishes, are also an excellent source of vitamin D. With many species, oil of high vitamin A and D content can also be obtained from portions of the viscera other than the liver. The body oils of fish are as a rule poor sources of vitamins.

Comprehensive tables of the vitamin A and D content of fish livers and viscera have been compiled by Butler (1946). Limited data from these tables are summarized in Tables 7 and 8. For more detailed information on other species the original report of Butler (1946) should be consulted. In general the livers of the true fishes (Teleostomi) range between 1 and 5% (usually between 1 and 2%) by weight of the total weight of the whole fish. The weight of the livers of the sharks and related species (Elasmobranchii) usually represent between 5 and 15% of the entire weight of the whole fish. Whether or not the liver of a given species can be profitably used as the raw material from which a vitamin A oil may be extracted will depend upon not only the vitamin A content of the extracted oil, but also upon both the percent oil in the liver and the relative size of the liver with respect to the size of the whole fish.

Owing to the pre-eminent position of fish and especially fish-liver oils as a source of vitamins A and D, it is often overlooked that sea foods are also rich in certain other vitamins. Only limited data are available on the water-soluble vitamin content of fish. Some of these data are summarized in Table 9.

Fish flesh is a fair source of thiamine, being somewhat poorer in this vitamin than most meats. Shellfish and crustacea probably have a higher thiamine content than fish. Thus Fellers and Harris (1940) report Atlantic crab to contain 230 micrograms thiamine per 100 g. crab meat, a value comparing very favorably with those of meats. Fish roe is a very excellent source of thiamine, ranking with the best food sources in this respect. Fish liver also contains relatively large quantities of this vitamin.

Of considerable interest is the relationship between consumption of certain whole fresh-water fishes by foxes or other fur-bearing animals to the thiamine content of the diet. Thus Green, Carlson, and Evans (1942) report that foxes fed whole carp developed Chastek paralysis. This disease failed to develop, however, when the diet was supplemented with 10 mg. or more of thiamine per day. The disease did not develop following feeding upon carp flesh only, nor did it occur if whole carp were fed intermittently for several days a week and a diet containing adequate thiamine on other days.

TABLE 7.--Vitamin A content of oils from some fishery sources[1]

Common name	Scientific name	Area in which fish are caught	Source of oil	Percent of round weight[2]	Oil content Percent	Vitamin A content in U. S. Pharmacopoeia units per gram of oil: Range Units per gram		Average Units per gram
Soupfin shark	Galeorhinus zyopterus	Pacific (male)	liver	10	55-68	45,000-	200,000	120,000
" "	" "	" (female)	"	10	65-72	15,000-	40,000	32,000
Grayfish (dogfish)	Squalus sucklevi	" -Alaska	"	10	67-72	2,000-	20,000	5,000
" "	" "	" -Hecate Strait	"	10	65-70	7,000-	15,000	10,000
" "	" "	" -Wash.-Ore.	"	10	50-70	8,000-	25,000	14,000
" "	" "	" -N. Calif.	"	10	62-68	12,000-	20,000	15,000
Halibut	Hippoglossus hippoglossus	Pacific-Area 3 [3]	liver	1.5-3	8-21	40,000-	160,000	87,000
"	" "	" " 2 [4]	"	1 -1.75	17-27	20,000-	65,000	40,000
"	" "	" "	viscera[5]	2.5-5	2-5	70,000-	700,000	200,000
Sablefish	Anoplopoma fimbria	Pacific	liver	2 -2.5	10-26	50,000-	190,000	90,000
"	" "	"	viscera	3 -4	5-12	70,000-	250,000	125,000
Lingcod	Ophiodon elongatus	Pacific	liver	1 1.5	8-20	40,000-	550,000	175,000
"	" "	"	viscera	1.8-3	4-15	10,000-	175,000	40,000
Sleeper shark	Somniosus microcephalus	Pacific	liver	10 -15	40-55	5,000-	15,000	7,000
Mud shark	Hexanchus griseus	"	"	10 -15	60-65	5,000-	7,000	7,500
Great blue shark	Priomace glauca	"	"	6/	30-45	7,000	27,000	20,000
Albacore tuna	Germo alalunga	Pacific	liver	1.5-2	7-20	10,000	60,000	25,000
Bluefin tuna	Thunnus thynnus	"	"	6/	4- 6	25,000-	100,000	75,000
Yellowfin tuna	Neothunnus macropterus	"	"	6/	3- 5	35,000-	90,000	50,000
Skipjack tuna	Euthynnus pelamys	"	"	6/	4- 6	30,000-	60,000	40,000
Bonito	Sarda chiliensis	"	"	6/	4-12	15,000-	60,000	35,000
Swordfish	Xyphias gladius	Pacific-Atlantic	liver	1.4-2.6	8-35	20,000-	400,000	250,000
"	" "	" "	viscera	3 -6	6-12	2,000-	30,000	10,000
Black sea bass	Stereolepis gigas	Pacific	liver	6/	13-20	100,000-	1,000,000	300,000
Cod	Gadus callarias	Atlanta	liver	3 - 5	20-60	1,000-	6,000	2,000
Rosefish	Sebastes marinus	"	waste[7]	6/	2-4	3,000-	5,000	6/
Rockfish	Sebastodes	Pacific	liver	1 -1.5	5-25	14,000-	300,000	6/
"	"	"	viscera	1.5-2.5	2-15	15,000-	125,000	6/
Petrale sole	Eopsetta jordani	Pacific	liver	1 -1.5	6-25	4,000-	175,000	6/
Herring	Clupea pallasii	"	body	6/	5-25	50-	300	90
Pilchard	Sardina caerulea	"	"	6/	5-25	50-	800	100
Menhaden	Brevoortia tyrannus	Atlantic	"	6/	5-20	500		6/

1/ These data compiled from reports of research at the laboratories of the Fish and Wildlife Service and of the Fisheries Research Board of Canada, and from articles published by representatives of commercial processors of fish livers and viscera. For the most part, the data are based on large lots of material or on samples taken over the normal season for the species. Vitamin D data for some of these species are included in Table 3.

2/ Percent of round weight means the proportion of liver weight to the weight of the entire fish (undressed) expressed as percent.

3/ Area 3 is defined by the International Halibut Commission regulations as follows: "Area 3 shall include all the convention waters off the coast of Alaska that are between Area 2 and a straight line running south from the southwestern extremity of Cape Sagak on Umnak Island, at a point approximately latitude 52° 49' 30" N., longitude 169° 07' 00" W., according to Chart 8802, published January, 1942, by the United States Coast and Geodetic Survey, and that are south of the Alaska Peninsula and of the Aleutian Islands and shall also include the intervening straits or passes of the Aleutian Islands."

4/ Area 2 includes: "all convention waters off the coasts of the United States of America and of Alaska and of the Dominion of Canada between Area 1B and a line running through the most westerly point of Glacier Bay, Alaska, to Cape Spencer Light as shown on Chart 8304, published in June, 1940, by the United States Coast and Geodetic Survey, which light is approximately latitude 58° 11'57"N., longitude 136° 38'18"W., thence south one-quarter east and is exclusive of the areas closed to all halibut fishing in Section 9 of these regulations."

5/ Viscera, unless otherwise designated, means the contents of the body cavity minus the liver, stomach, and gonads.

6/ The source from which information listed here was obtained did not supply data under this heading.

7/ Waste is the entire body of the rosefish minus the fillet or edible portion. It includes head, backbone, skin, and viscera.

It has been shown by Krampitz and Woolley (1944) that certain uncooked fresh-water fish contain an enzyme which splits thiamine into two cleavage products. Neilands (1947) has analyzed the thiaminase content of muscle and viscera of 12 fresh-water and 28 salt-water fishes. Except in the case of certain shellfish the salt-water species contained negligible quantities of the enzyme while the fresh-water species nearly all contained a considerable concentration.

Fish flesh is a good source of riboflavin, ranking about the same as meat, and fish roe and fish livers are extremely rich sources of this vitamin. Billings, Beely, Fisher, and Hedreen (1941) have shown that commercial fish meal contains extremely high quantities of riboflavin. Thus samples of commercial pilchard, salmon, and herring meals assayed between 900 and 2,200 micrograms per 100 g. of meal. Special meals prepared from the livers of salmon, tuna, pilchard, and herring contained (on a moisture- and fat-free basis) 5,000 to 10,000 micrograms per 100 g. of meal.

TABLE 8.--Vitamin D content of oils from fisher sources

Common Name	Scientific Name	Area in Which Fish are Caught	Source of Oil	Vitamin D Content in International units per gram of oil
				Units per gram
Albacore tuna	Germo alalunga	Pacific	liver	20,000--250,000
Bluefin tuna	Thunnus thynnus	"	"	20,000--70,000
Yellowfin tuna	Neothunnus macropterus	"	"	10,000--45,000
Skipjack tuna	Euthynnus pelayms	"	"	25,000--250,000
Bonito	Sarda chiliensis	"	"	50,000
Swordfish	Xyphias gladius	"--Atlantic	"	2,000--25,000

As shown in Table 9 fishery products are a very good source of vitamin B_6 and a fairly good source of niacin.

TABLE 9. -- Content of certain vitamin B complex substances in fish flesh

Substance	Thiamine micrograms per 100 gm.	Riboflavin micrograms per 100 gm.	Pyridoxine Units per 100 gm.	Niacin Mg. per 100 gm.
Cod	60	160	50	2
Flounder	105	68	...	...
Haddock	...	...	100	0.9
Halibut	45	47	...	...
Herring	23	217	...	...
Mackerel	120	280	...	...
Rockfish, red	55	...	...	...
Salmon, red	148	72	...	...
Salmon, pink	143	46	...	...
Salmon, chum	80	59	...	...
Salmon, silver	87	109	...	...
Salmon, king	101	231	...	...

7. Miscellaneous Substances in Fish

In addition to the principal nutritive components of fish, protein, minerals, oil and vitamins, there occur many other substances far too numerous to completely list here. Numerous nonprotein nitrogen compounds are present. In addition to free amino acids, various basic nitrogen compounds occur. Beatty (1939) reports various Teleost salt-water fishes to contain an average of 0.31 to 0.67% trimethylamine exide in the press muscle juice. In dogfish an average of 1.25% was found to be present. Fresh-water fish were shown to contain no trimethylamine oxide. The oxide decomposes during spoilage to give trimethylamine and small amounts of dimethylamine. Creatine phosphoric acid is reported by Zagami (1929) to be present in the muscle of fish in quantities ranging from 0.1 to 0.6% and it is shown that there is a correlation between the content of this substance and the muscular activity of the fish, those migrating over the larger distances having higher content of the phosphagen.

Small quantities of formaldehyde have been reported in fish, especially in canned fish. Early investigators attributed its presence in canned fish to slow oxidation of trimethylamine which led to increasing concentrations over prolonged storage of the canned product. While such a reaction may take place the presence of formaldehyde in fresh (uncanned) fish has been shown by Lunde and Mathieson (1934).

Pigments occur in the fresh and oil of some species of fish. Bailey (1937) has reviewed the literature and contributed some experimental work on the pigments in salmon. The red pigment is identified as a form of astacin, also known to occur in the lobster. Beely and Chalmers (1936) believe the principal yellow pigment present in pilchard oil is fucoxanthin. Other pigments believed to be present in small quantities in some fish include carotene and chlorophyll.

Glycogen is present in the flesh of fish, and, as in mammals, it functions as a source of stored energy, yielding lactic acid through a series of reactions. Oysters contain especially large quantities of glycogen (up to 2 or 3% in the meats); other species contain a few tenths per cent. The transformation to lactic acid, completely reversible in the living fish, becomes irreversible after death so that as a result of postmortem changes, the lactic acid content rises from a few hundredths per cent in the living muscle to a value of 0.3 to 0.5% when full rigor mortis is attained.

The pH of the flesh of most species of fish is between 6.6 and 6.8 immediately after death. As lactic acid accumulates the pH falls, but owing to the excellent buffering action of the flesh, the decrease is not great, and in the case of the muscle of fish, a drop below pH 5.8 is exceedingly rare. As spoilage takes place, an accumulation of basic end products such as trimethylamine and ammonia occurs so that the pH then rises, slowly at first and then quite rapidly, reaching a value of 7.5 to 8.0 in extreme spoilage. In the case of oysters no rise in pH occurs, since spoilage in this species takes place as a souring of the product due to accumulation of large quantities of lactic and other acids. In extreme spoilage the pH of oysters may fall to 4.8 or lower.

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52982 Interior-Duplicating Section, Washington, D.C.