Lipids and Fatty Acids of Important Finfish: New Data for Nutrient Tables

J. EXLER, Nutrient Data Research Center, Consumer and Food Economics Institute,[1] Hyattsville, Maryland 20782, **J.E. KINSELLA**, Department of Food Science, Cornell University, Ithaca, New York 14850, and **B.K. WATT**, Nutrient Data Research Center, Consumer and Food Economics Institute,[1] Hyattsville, Maryland 20782

ABSTRACT

There is an urgent need for thorough and reliable information on the lipid content and fatty acid composition of food. Data on fish lipids (1960 to the present) have been collected and evaluated for the preparation of nutrient and food composition tables for this important commodity. Some factors affecting these data include the lack of standardization in fish nomenclature, cut of fish, season and location of catch, and variability of methods of analysis. The derivation and use of conversion factors relating wt percent methyl ester data in the literature to g fatty acid/100 g fish are described. Tabulated data are presented for total lipid and 14 fatty acids in 11 important finfish.

INTRODUCTION

The National Nutrition Consortium, Inc., representing the American Institute of Nutrition, the American Society for Clinical Nutrition, the American Dietetic Association, and the Institute of Food Technology, has proposed a series of guidelines for a national nutritional policy (1). One area specified as a means of attaining the goal of establishing and effectively implementing such a policy is the continuous study, assessment, and accumulation of information related to the nutrient composition of foods. It has been emphasized that a food and nutrition policy will have to include, as necessary components, research support for improved methodology for the nutrient analysis of food and systematic research for collection of nutrition data on all currently known foods (2). These reports (1,2), along with the institution and widespread use of nutritional labeling (3), emphasize the growing need for thorough and reliable information on the nutrient composition of all foods.

[1]ARS, USDA.

Recognizing that need, the Nutrient Data Research Center (NDRC) of the Consumer and Food Economics Institute at USDA has been actively engaged in collecting, evaluating, and tabulating food composition data from a variety of sources (4,5). An important result of this work will be the establishment of a Nutrient Data Bank and the publication of the successor to *Agriculture Handbook* No. 8 (6). More specifically, a group was formed at NDRC in 1973 to assemble all available data on the lipid and fatty acid content of food (7).

The nutritional significance of fish lipids has been the subject of extensive reviews (8-12). Particular interest has been shown toward the total lipid content and the fatty acid composition of fish, especially the long chain, highly unsaturated fatty acids which, as shown in Table I, distinguish fish lipids from the lipids of most other foods. Although *Agriculture Handbook* No. 8 (6) includes data on the nutrient composition of ca. 100 species of fish, limited fatty acid information is given for only 9 fish. Therefore, it is not only necessary to revise the given data for fish, but an extensive compilation of available fatty acid data is most urgent. The purpose of this paper is to describe that compilation for finfish, both marine and freshwater.

SOURCE OF DATA

The major source of data has been the scientific and technical literature, representing reports from industry, governmental agencies, and academic institutions. Because

TABLE I

Usual Range of Fatty Acids as Wt Percent in Several Food Commodities

Fatty acid[a]	Butterfat[b]	Lard[b]	Soybean[b]	Marine fish[c]	Freshwater fish[c]
4:0	2.8-4.0				
6:0	1.4-3.0				
8:0	0.5-1.7				
10:0	1.7-3.2				
12:0	2.2-4.5				
14:0	5.4-14.6	1-4		2-8	2-6
16:0	26-41	20-28	7-11	10-30	10-20
18:0	6.1-11.2	5-14	2-6	2-6	3-4
20:0	1.2-2.4		0.3-3		
14:1	0.6-1.6				
16:1	2.8-5.7			2-11	7-11
18:1	18.7-33.4	41-51	15-33	12-28	18-28
18:2	0.9-3.7	2-15	43-56	1-3	4-6
18:3		tr.-1	5-11	0.5-1.2	3-5
18:4				0.7-4	1-2
20:1	0.8-3.0			1-10	1-3
20:4		0.3-1		0.5-4	2-4
20:5				6-14	5-7
22:1				1.5-9	0.5-3
22:5				0.6-3	2.5-4
22:6				8-20	8-20

[a]Carbon atoms:double bonds.
[b]From ref. 13.
[c]From ref. 11.

TABLE II

Several Species of "Flounder" and Lipid Content of Their Fillets

Common names	Scientific names	Total lipid[a]	Reference
Dab flounder Sea dab Long rough dab American plaice	*Hippoglossoides platessoides*	0.66	17
Greyback flounder Witch flounder Grey sole	*Glyptocephalus cynoglossus*	0.86	18
Plaice (European)	*Pleuronectes platessa*	1.16 1.5	19 20
Yellowtail flounder Rusty dab Longhead dab	*Limanda ferruginea*	1.20	21
Winter flounder Blackback flounder Lemon sole	*Pseudopleuronectes americanus*	1.4	22

[a]Percent of sample.

TABLE III

Total Lipid Content of Steaks from Different Portions of Fish

Fish	Total lipid (percent of sample)		Reference
	Thick steak	Tail steak	
Haddock[a]	0.71	0.77	29
Pacific halibut[b]	0.9	0.7	30
Cod[c]	0.96	1.15	31
Cod	0.92	1.17	32
Atlantic halibut, whole[d]	3.1	1.2	33
Atlantic halibut, white	1.14	0.74	33
Atlantic halibut, dark	8.5	3.9	33
Pink salmon[e]	4.3	2.7	34
Coho salmon[f]	7.76	3.41	35
Atlantic mackerel, winter[g]	18.8	12.6	36
Atlantic mackerel, summer	3.2	4.9	36

[a]*Melanogrammus aeglefinus.*
[b]*Hippoglossus stenolepis.*
[c]*Gadus morhua.*
[d]*Hippoglossus hippoglossus.*
[e]*Oncorhynchus gorbuscha.*
[f]*Oncorhynchus kisutch.*
[g]*Scomber scombrus.*

of the backgrounds of the authors (nutrition, food science, biochemistry, and analytical chemistry), the approaches taken in the papers have varied, and the information reported has not always been in a form readily useable for food composition tables. Therefore, careful evaluation of the data as to their ultimate usefulness for food composition tables was often necessary.

At present, the fatty acid composition of various cuts of over 100 different species of finfish has been recorded on almost 500 separate data work sheets (CFE Form 22). Ca. one-third of the reports that were recorded were published in the U.S., one-fourth in Japan, and one-fourth in Canada and England; and, of the remainder, no single country contributed greater than 3%.

DATA AND RELATED PROBLEMS

Considering that over 500 data work sheets already have been recorded and the number of reprints that are anticipated in the future, it would seem that there are sufficient data with which to work. However, because of the different sources of data (country, type of journal, background of researcher, etc.), the reports are useful only to varying degrees. Some of the limitations in the data are considered below. All data, unless otherwise noted, are for raw, fresh fish; only limited data are available for processed fish products. Fish with less than 5% fat are lean, and those with greater than 5% are fat.

Nomenclature

Both the scientific and common names of the given species of fish were recorded. Unfortunately, there has been some confusion due to the lack of standardization in the nomenclature of fish. For example, rock or rockfish (*Morone saxatilis*), common to the Chesapeake Bay arēa, is actually a striped bass and is distinct from the various species of rockfish (*Sebastodes* spp.) indigenous to the West Coast of the U.S. Albacore, the white meat canned tuna, has been classified variously as *Germo alalunga, Thunnus germo,* and *Thunnus alalunga,* the last being the most recently used (14-16). Several species of "flounder," their alternate common names, and the total lipid content of their fillets are given in Table II. It is clear that some form of agreement must be reached in the naming of fish.

The National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, is currently responsible for the market nomenclature of fish and fishery products (23,24). Until such time as that nomenclature is standardized, several useful references (25-28) will be used for species identification.

TABLE IV

Seasonal Variation in Lipid Content of Mackerel (*Scomber scombrus*) Caught off Northeast and Northwest Atlantic (7)

	Total lipid (percent of sample)			
	Northeast	Northwest		
Season	Fillet/whole	Fillet	Light meat	References
Spring	16.1-19.1	8	2.2-4.9	36,40,41
Summer	3.9-9.1	-	4.6-7.6	40-42
Fall	9.9-14.3	8.6-25.5	10.2-18.8	36,40,41,43
Winter	15.7-24.1	-	-	40,42

TABLE V

Seasonal Trends in Fat Metabolism and Sexual Cycles of Fish from Mediterranean Sea (47)

	Season	
Activity	Heat-loving fish[a]	Cold-loving fish[b]
Fat deposition	Summer and fall	Spring and summer
Fat consumption	Winter and spring	Fall and winter
Sexual maturation	Spring	Fall
Spawning	Summer	Winter

[a]Anchovy (*Engraulis encrasicholus*) and red mullet (*Mullus barbatus*).
[b]Sprat (*Sprattus phalericus*) and sardine (*Sardina pilchardus*).

TABLE VI

Effect of Type of Pack upon Lipid Composition of Yellowfin Tuna (*Thunnus albacares*) (21)

	Lipid composition[a]	
Lipid component	Brine pack	Oil pack
Total lipid	1.38	14.49
Linoleic acid (C 18:2)	0.4	31.2
Eicosapentenoic acid (C 20:5)	12.6	4.6
Docosahexenoic acid (C 22:6)	32.3	23.3

[a]Total lipid given as percent of sample. Fatty acids given as percent of total fatty acids.

Portion Analyzed

The total lipid content and fatty acid composition vary with the cut of the fish. In general, tail steaks contain less lipid than thick steaks ahead of the dorsal fin, except for lean fish (12). This variation is shown in Table III for both lean and fat fish. The dark muscle of cod (*Gadus morhua*), a lean fish, contains 3 times as much lipid as does the light muscle (37); and, in the Baltic herring (*Clupea harengus*), the ratio is ca. 4.5 to 1 (38). Generally speaking, the "notch" flesh at the dorsal and ventral fins, the lateral line tissue, and the belly flap are all higher in total lipid content than the relatively lean white muscle.

The lack of uniformity in the description of the tissue extracted has caused some confusion and uncertainty in the comparison of data from several sources. Where the description of the cut of fish has been reported as tissue, flesh, meat, or muscle, it has been assumed that the portion referred to is fillet. Wherever possible, other information will be related to the various market forms of fish with which the consumer is familiar.

Season of Catch

Those lean fish in which the total lipid is predominantly phospholipid show very little seasonal variation in their flesh lipid. For example, the range of total lipid content for cod fillet is 0.6-0.8% (39); and, for haddock (*Melanogrammus aeglefinus*), the reported range is 0.7-0.8% (29). However, the livers of these lean fish, which serve as storage depots for triglyceride, exhibit a much greater variation in total lipid content, with cod liver increasing from a low of 15% in spring to a high of 75% in fall (39).

The fat fish which store triglycerides in their flesh are reported to have a maximum total lipid content in the summer when food is plentiful. Total lipid decreases in fall and winter to a minimum value in late winter and then begins to increase in the spring (12). However, in assembling the literature data, exceptions to this trend were observed. Table IV shows accumulated data on Atlantic mackerel (*Scomber scombrus*), as summarized by Kinsella, et al. (7). Whole Lake Michigan alewife (*Alosa pseudoharengus*) have their lowest total lipid content in early summer and their highest in the fall (44). Herring fillet (38) and frozen whole herring (45) exhibit a similar variation with minimum values for total lipid in spring and maximum values in late fall. It has been suggested by Leim (46) that the lipid content in herring depends upon the availability of food and sexual maturation, total lipid being lowest prior to and during spawning and highest during the months of active feeding.

In studying fish from the Mediterranean Sea on the basis of their trends in fat metabolism and sexual development, Shul'man (47) distinguished between heat-loving and cold-loving fish (Table V). The environmental temperature differences influence the amount of total lipid deposited with a range of 5-6% for heat-loving fish and 16-24% for cold-loving fish. One species of pilchard (*Sardinella aurita*) inhabiting the northern and southern ends of the Meditarranean exhibits both trends depending upon the location. Because of the variability of total lipid, it is important that both season and location of catch be reported, since this information is useful for arriving at yearly average values.

Methods

Major problems have arisen from the methods used in sampling and analytical procedures. Usually, sampling was from a pool of several fish or from a selected number of individual fish from which an average value was determined. Frequently a single fish caught at a given location and season was the basis of reported data. Therefore, published data must be evaluated very carefully.

Most samples studied were raw, fresh fish, although occasionally whole animals, or their flesh, were frozen, can-

TABLE VII

Sample Data Used in Calculation of Conversion Factors

Fish, description	TL[a]	TG[b]	PL[c]	F[d]	Reference
Atlantic cod, fillet *(Gadus morhua)*	0.75	7.7	86.2	0.69	37
Atlantic cod, flesh	0.61	6.4	87.3	0.69	53
Atlantic herring, whole *(Clupea harengus)*	16.4	92.6	6.9	0.94	54
Baltic herring, fillet	4.6	71.9	25.0	0.87	55
Cornish mackerel, flesh (Dec.) *(Scomber scombrus)*	24.1	94.1	3.5	0.92	40
Cornish mackerel, flesh (June)	9.1	87.2	9.7	0.90	40

[a]Total lipid (TL) as percent of sample.

[b]Triglyceride (TG) as percent of total lipid.

[c]Phospholipid (PL) as percent of total lipid.

[d]Factor (F) = TG (decimal) x 0.956 + PL (decimal) x 0.72.

ned, or dried prior to analysis. Freezing for relatively short periods and canning have little effect upon fatty acid composition (11). Flavor alterations render fish unfit for human consumption before oxidation alters fatty acid composition (10). Cod fillets frozen for 9 months at -12 C showed a decrease in phospholipids, a slight decrease in triglycerides, and a corresponding increase in free fatty acids (37). In a study of four species of tuna, it was found that canning resulted in no significant reduction of unsaturation (15). Significant changes in fatty acid composition were caused by canning in vegetable oil whose composition masked that of the fish oil (Table VI). It is expected that some alteration of lipid composition during drying of fish occurs because of the large amount of easily oxidized polyunsaturated fatty acids present in fish.

The choice of extraction method must take into consideration the presence of polar lipids in fish tissue, especially in lean fish. The most reliable data are derived from the use of a two solvent system for the extraction of total lipid (18,48,49). Ca. one-half of the data recorded was based upon this method; the other half using different or unknown methods. Unfortunately, information in the literature on the methods used is not always detailed enough to indicate the reliability of the data. This also applies equally for the fractionation of total lipid into classes, the saponification of the total lipid extract or its classes, and the preparation of fatty acid methyl esters.

The separation of the fatty acid methyl esters by gas liquid chromatography and the subsequent identification and quantification of peak areas have resulted in abundant data on the fatty acid composition of fish. Because of the wide variation and the degree of unsaturation of fish fatty acids, exact details of the analytical procedures should be given in all papers (50-52). These details should include description of liquid phase, solid support, size of column, temperatures, carrier gas, flow rate, sample size, type of detector, method of peak area determination, and standards

TABLE VIII

Conversion Factors (F) Based upon Total Lipid (TL) Content of Fish (7)[a]

TL	TG	PL	F
0.65	--	92.3	0.66
0.70	7.1	85.7	0.68
0.80	18.8	75.0	0.72
0.90	27.8	66.7	0.75
1.00	35.0	60.0	0.77
1.25	48.0	48.0	0.80
1.50	56.7	40.0	0.83
1.75	62.9	34.3	0.85
2.00	67.5	30.0	0.86
2.50	74.0	24.0	0.88
3.00	78.3	20.0	0.89
3.50	81.4	17.1	0.90
4.00	83.8	15.0	0.91
4.50	85.6	13.3	0.91
5.00	87.0	12.0	0.92

[a]Assuming that phospholipid (PL) content was 0.6 g/100 g edible portion, sterols (cholesterol) were 0.05 g/100 g edible portion, and conversion factors of 0.956 and 0.72 were used for triglycerides (TG) and phospholipids, respectively.

TABLE IX

Lipid Data on Commercially Important Finfish

Fish		Cut	Total lipid[a]	Conversion factor[b]
Common name	Scientific name			
Channel catfish	*Ictalurus punctatus*	Fillet	3.6	(0.90)
Atlantic cod	*Gadus morhua*	Fillet	0.73	0.69
Yellow flounder	*Limanda ferruginea*	Fillet	1.2	(0.80)
Haddock	*Melanogrammus aeglefinus*	Fillet	0.66	0.61
Atlantic halibut	*Hippoglossus hippoglossus*	Fillet	1.1	0.78
Atlantic (Baltic) herring	*Clupea harengus*	Whole	16.4	0.94
Atlantic mackerel	*Scomber scombrus*	Fillet	12.6	0.93
Ocean perch	*Sebastes marinus*	Fillet	2.5	(0.88)
Red (sockeye) salmon	*Oncorhynchus nerka*	Fillet	8.9	(0.93)
Albacore tuna	*Thunnus alalunga*	White meat	8.0	(0.93)
Whiting (silver hake)	*Merluccius bilinearis*	Fillet	3.8	(0.91)

[a]Percent of sample.

[b]Values imputed from Table VIII are in parentheses.

TABLE X

Fatty Acid Composition of Important Finfish as g Fatty Acid/100 g Fish[a]

Fatty acid	Channel catfish	Atlantic cod	Yellowtail flounder	Haddock	Atlantic halibut	Atlantic herring	Atlantic mackerel	Ocean perch	Red salmon	Albacore tuna	Whiting
14:0	0.05	0.01	0.05	0.01	0.01	0.84	0.59	0.11	0.27	0.22	0.17
16:0	0.62	0.10	0.16	0.08	0.13	1.9	2.1	0.26	0.93	1.6	0.52
18:0	0.20	0.02	0.07	0.02	0.06	0.18	0.47	0.06	0.20	0.33	0.09
16:1	0.13	0.01	0.07	0.02	0.03	2.0	0.66	0.15	0.44	0.39	0.30
18:1	1.0	0.06	0.11	0.06	0.10	2.3	2.1	0.42	0.99	1.4	0.58
18:2	0.22	--[b]	0.01	0.01	--	0.15	0.18	0.03	0.79	0.16	0.07
18:3	0.02	--	0.01	--	--	0.10	0.13	0.05	0.44	0.19	0.13
18:4	0.02	--	0.02	--	--	0.16	0.25	0.04	0.10	0.14	0.08
20:1	0.02	0.01	0.03	0.01	0.03	2.0	0.83	0.19	0.07	0.22	0.12
20:4	0.08	0.02	0.04	0.01	0.02	0.10	0.15	0.15	1.1	0.14	0.27
20:5	0.15	0.08	0.10	0.05	0.10	1.1	0.84	0.18	0.65	0.63	0.32
22:1	--	--	--	--	0.02	2.9	1.1	0.14	0.06	0.12	0.02
22:5	0.07	0.01	0.05	0.01	0.01	0.08	0.19	0.03	0.52	0.06	0.06
22:6	0.34	0.15	0.11	0.10	0.30	0.71	1.5	0.26	1.5	1.7	0.43
Other	0.27	0.01	0.14	0.03	0.06	0.95	0.66	0.14	0.20	0.08	0.30

[a]See Table IX for further details on species.
[b]Not present or less than 0.005 g.

used for identification of fatty acids. Publication of such information will facilitate comparison of data from different sources.

Lipid Data

The type of data reported varied considerably from one source to another. For some fish, only total lipid, lipid class composition, or fatty acid methyl ester wt percent was given. In such cases, it was necessary to combine the data from several sources, thus incurring the risk of using information obtained by employing different analytical methods. Complete data from a single reference (from total lipid content to fatty acid composition with adequate description of methods) were most useful in calculating the amounts of fatty acids in either total lipid or edible portion of food.

Because of inadequate description and poor analytical methods, good data were not always readily available, and it sometimes was necessary to record data of questionable reliability. These limited data were used when they could be compared with reliable information; but, where no comparison was possible, such data were not used. It is hoped that future research will enable the gaps to be filled in.

Calculations

The method of calculating either g fatty acid (FA)/100 g fish or g fatty acid/100 g total lipid (TL) necessitates the derivation of a reasonable factor (F) relating the total amount of fatty acids to a given quantity of total lipid, i.e. g total fatty acids/g total lipid. This factor is calculated easily where lipid class composition is given, and the calculation is based upon the facts that, on the average, 1 g triglyceride (TG) contains 0.956 g fatty acid and 1 g phospholipid (PL) contains 0.72 g fatty acid, With the percent of total lipid expressed as a decimal, the calculation involved is as follows:

$$TG \times 0.956 + PL \times 0.72 = F \text{ (decimal)}.$$

Sample data are given in Table VII.

Where specific data are not available for performing these calculations, other methods of arriving at reliable factors must be employed. A preliminary estimation of factors, as appeared in a recent paper (7), is shown in Table VIII. The procedure is being revised, and a detailed description will appear in a future publication.

The factor is used to convert fatty acid methyl ester data to values suitable for food composition tables. It is assumed that, because the average fatty acid mol wt in fish lipid is relatively high, the methyl ester data can be used as corresponding to fatty acid wt percent. Calculations then proceed as follows:

$$F \times FA = \text{g FA/100 g TL}$$
$$F \times FA \times TL \text{ (decimal)} = \text{g FA/100 g fish}$$

It is these final values that are in the forms useable for food composition tables.

PRELIMINARY TABLES

Tables IX and X represent an interim summary of data accumulated on 11 important finfish in terms of both volume and value of landings (27). All of the fish are marine in origin, except for the freshwater channel catfish (*Ictalurus punctatus*), and the data on red salmon and albacore tuna include some analyses on samples canned as dietary pack (without vegetable oil).

The common and scientific names of the various species, together with pertinent data, appear in Table IX. Cuts of fish are related to the consumer recognizable market forms, with whole herring and white meat albacore being the only exceptions to the standard fillet. Values for total lipid and fatty acid composition were averaged from as much information as was available over a range of seasonal and geographic data; the results, therefore, represent yearly averages from a variety of sources. Although information on some fish was from a limited number of references and represents a restricted composition, the data are include here for comparative purposes. Factors were calculated, where possible, from data on lipid class composition. Other factors, in parentheses, were derived from total lipid data by using the method shown in Table VIII.

The amounts of the 14 most commonly occurring fatty acids in fish are given in Table X. Although some are only a few percent of the total fatty acids, they are nutritionally important, because they belong to the linoleic and linolenic families of fatty acids with double bonds located six and three carbon atoms from the methyl terminal end of the chain, respectively. The designation "other" refers to those unidentified, odd-numbered, branched chain, or minor components not included in the list of major acids. Because of the low content of total lipid in some fish, the data on g fatty acid/100 g fish are given to 2 significant figures.

It is hoped that this article, by summarizing the problems involved in the accumulation of data, will stimulate much needed research and publication of useful and complete information on the lipid components of fish. Such information would further the establishment of a Nutrient Data Bank and the revision of food composition tables and benefit nutritionists, food scientists, and the consuming public.

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