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The Proximate and Lipid Composition of Several Species of Freshwater Fishes*

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INTRODUCTION

Information concerning the chemical composition of freshwater fishes is useful to ecologists and environmentalists who are interested in determining the effects of changing biological/environmental conditions on the composition, survival, and population changes within fish species. It is also valuable to nutritionists concerned with readily available sources of low-fat, high-protein foods such as most freshwater fishes, and to the food scientist who is interested in developing them into high-protein foods while ensuring the finest quality flavor, color, odor, texture, and safety obtainable with maximum nutritive value. In the future, given the anticipated development of aquaculture, knowledge of the nutrient composition of freshwater fishes and of the relationship between their chemical composition, food value, and stability while being processed into acceptable edible products will become of significant practical interest. These factors, plus the potential of exploiting presently unused freshwater species for developing high-protein foods for a vast world market, underscore the need for reliable analytical data.

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The unique position of fish as a source of low-fat, high-protein, highly nutritious food makes development of new fish products economically attractive and desirable because the number of persons who require special diets that are low in fat but high in unsaturated fatty acids is increasing. This fact, which should be appreciated by virtue of its economic significance alone, was recently emphasized by Stansby (1973). However, new food products, although highly recommended for their nutritive value, have limited markets unless they are attractive to the consumer. Chemical components, and lipids in particular, are potential sources of problems in materials being developed as food products. Many consumers are offended by off-odors and off-flavors, particularly in reacting to new food products, and especially those derived from fish. The lipids in fish flesh are highly unsaturated and oxidize very rapidly to produce carbonyl compounds (aldehydes, ketones) which impart off-flavors to low-fat foods, (e.g., lean fish filets) at concentrations as low as parts per billion. Thus in developing new products, thorough knowledge of the lipid and fatty-acid composition is essential in order to clarify their role(s) in food quality.

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Significance

Lipids occur in fish in the muscle, adipose, and liver. All muscle lipids are highly unsaturated and thus unstable, but those of the dark muscle are the most unstable (Stansby, 1967; Ackman, 1974). In addition, fish muscles have very active lipases that hydrolyze ester lipids and release free fatty acids. These fatty acids cause deterioration in fish and fish products (Love, 1964).

Lipids affect texture. Tenderness in fish products is associated with the solubility and water-holding capacity of muscle proteins. However, fish and fish products become tough, "dry", and gritty during storage, even when frozen (Ackman, 1967a; Love, 1964; Olley, 1969). This is a major problem that is apparently caused by the free fatty acids. These are released by endogenous lipases, which are activated when the fish tissue is ruptured during deboning or homogenizing. The accumulating fatty acids gradually reduce solubility of the muscle myosin, which in turn aggregates and then loses water as drip during thawing. The net result is tough, dry fish with inferior texture (Love, 1964; Dyer, 1968; Anderson, 1964). The enzymes involved are general lipases acting on trigly-cerides and phospholipases acting on phospholipids. More basic information is needed concerning the location and properties of these hydrolytic enzymes.

Lipids affect flavor. Rancidity, caused by free acids directly, but more significantly by the oxidation products of fatty acids, is the most important problem associated with the acceptibility of fish (Stansby, 1967; Ackman, 1967a, 1974; Dyer, 1966). A primary cause of deterioration in fresh fish, frozen fish and processed fish products is oxidation of the component lipids. Oxidation occurs via free-radical mechanisms, and because the fish fatty acids are highly unsaturated they oxidize very easily (Olcott, 1962). Free fatty acids oxidize more rapidly than those that are esterified, hence processes resulting in hydrolysis of acyl esters facilitate deterioration of fish products. Such processes as grinding, deboning, or comminution (pulverizing), which disrupt the tissue, break down natural barriers and facilitate hydrolysis of the lipids. The oxidation of free fatty acids results in several deleterious effects, the most obvious being the accumulation of carbonyls (aldehydes and ketones) which, even at very low concentrations, impart rancid flavors and make fish unpalatable, though safe and nutritious.

The oxidative degradation of unsaturated lipids produces hydroperoxides, acids, alcohols, aldehydes, ketones, furans, and semialdehydes. These chemicals can interact with proteins (i.e. dicarbonyl/epsilon amino group (lysine) condensation) to form polymers; with amino acids to form acyl esters (bitter taste); or with sugars and alcohols in aldol condensations, all of which result in product deterioration. This may be evidenced by changes in texture, flavor, odor, and color, making products unacceptable to the potential consumer. A significant result of autoxidation is the destruction of essential amino acids, lysine, methionine, and perhaps histidine, of vitamins such as C, E, thiamine, and ribo-flavin, and of the essential fatty acid, linoleic acid (Karel, 1975).

The interaction of peroxidizing lipids with tissue proteins and the resulting deleterious effects — for example, insolubilization, pigment formation, amino acid and vitamin destruction, and the development of malodors, bitter tastes, and gritty textures have been alluded to with regard to other food systems (Schultz, 1962; Karel, 1975; Ory, 1975), but their importance in fish and fish products has not been quantified, although it is very probable that several of these reactions may occur.

Lipids affect color. The heme pigments associated with dark muscles catalyze autoxidation of lipids. Oxidizing lipids in turn cause decomposition of heme pigments, which results in various off colors (Green, 1975). Because these reactions are interdependent, control of the initial step should be effective. The role of heme in lipid oxidation and off-color development in meat has been reviewed (Greene, 1975). However, little is known of this reaction in fish, where, particularly in comminuted products, various tissues containing hemoglobin are mixed.

The extent of these reactions may vary with fish species, their lipid content, and composition; processing regime; the portion(s) of fish used, particularly the amount of red muscles included; the extent of aeration, heat, and freezing; the nature of packaging used, and storage conditions.

These various deleterious reactions are significant where fishery products are intended for consumer markets, but much fundamental information is needed. Thus, for the successful, long-term development of freshwater fish resources and as a prerequisite for the successful use of several fish species as food per se or as food ingredients, accurate information on the chemical composition is necessary.

Present Status

Knowledge of the nutrient content and composition of freshwater fishes of the northeastern United States is scarce. Available information about the composition of freshwater fish species in general is scattered throughout the literature, and much of the data were obtained by obsolete analytical methods. Thurston et al. (1959) published proximate compositional data on a number of freshwater species, and Sidwell (1974) listed the proximal composition of 154 species, predominantly of marine origin. The need for reliable data concerning nutrients in fish and marine products has been repeatedly emphasized (Ackman, 1974; Kinsella et al., 1975).

Data on sterol content and composition are scarce (Sweeney and Weihrauch, 1977; Criner et al., 1972) and there are few data on the phospholipid content of freshwater fish species. Overall, knowledge of the lipid and fatty-acid composition is fragmentary and of limited use for quantitative application for several reasons, for example, the variety of sampling methods used, lack of description of portions analyzed, variable methodologies employed, and improper identification of fatty acids (Ackman, 1967b; Kinsella et al., 1975). The available information on finfish has been reviewed by Stansby (1967) and Ackman (1967a, 1974), and quantitative data were recently collated by Exler et al. (1975) and Exler and Weihrauch (1976). These reviews revealed the paucity of data on the fatty-acid content of freshwater finfish.

Therefore, in conjunction with the current research at Cornell University concerned with developing foods from freshwater fish species, a systematic study of the proximate composition and the detailed lipid and fatty-acid composition of several freshwater species inhabiting New York lakes was completed.

Materials and Methods

Sample Preparation

The smelt, suckers, and rainbow and lake trout were caught in Cayuga Lake, Ithaca, N.Y.; brook trout were caught in a local stream, and all remaining species of fishes analyzed were harvested from Oneida Lake at Bridgeport, N.Y. by personnel of the Cornell Biological Station. Before analysis, the head, tail, fins, viscera, and skin of the fish were removed. Fish filets were obtained by carefully cutting the fish lengthwise along the backbone to obtain maximum amount of flesh while excluding bones. The weight of each filet was determined. Because the different sections of the filets vary in composition depending upon their location (Stansby, 1973), the filets were cut into small portions ($1cm^2$), which were mixed before random samples were taken for the analyses.

All chemicals and organic solvents used were reagent grade (Fisher Scientific Co., Rochester, N. Y.), and distilled water was used in the analytical work.

Analyses

The proximate composition, phospholipid and sterol content, and fatty-acid composition of each species were determined. For sampling, from 3 to 10 fish were analyzed for each species. The moisture, lipid, and phospholipid content were determined on all of these fish samples. For determination of protein, ash, and sterol content, 3 individual, representative, fish samples of each species were analyzed.

Proximate Composition

Moisture content: Random samples of fish filets (2-3g) were weighed in duplicate in tared aluminum pans and heated in a forced-air oven (Precision Scientific, Chicago, Ill.) at 90°C to constant weight. Moisture content was determined by weight difference.

Protein content: Protein was determined by the Kjeldahl method (AOAC, 1970). Samples of dried fish filets (0.3–0.4g) were fully digested in 25 ml of concentrated sulfuric acid along with 0.7g mercuric oxide and 15g potassium sulfate. After digestion, 250 ml of water, 25 ml of a 4% potassium sulfide solution, and sodium hydroxide solution 50 ml, (50% by wt) were added to the digested sample. The ammonia was distilled into 2% boric acid (25 ml) and titrated against 0.1N hydrochloric acid with methyl red–bromcresol green as indicator. Protein was computed by multiplying the nitrogen value by 6.25.

Ash content: Ash content was determined according to the AOAC (1970) method. Samples of fish filets (2.0g) were dried in a crucible at 100°C in an oven. The dried sample was heated in a muffle furnace (Hoskins Co., Detroit, Mich.) at 525°C until a white ash was obtained. The ash was moistened with water, dried on a hot plate, and reashed at 525°C to a constant weight.

Lipids: The lipids were extracted by the method of Bligh and Dyer (1959) with slight modifications. Representative samples of fish filets (30g) were homogenized in a Waring blendor for 2 minutes with a mixture of methanol (60 ml) and chloroform (30 ml). One volume of chloroform (30 ml) was added to the mixture and, after blending for an additional 30 seconds, 30 ml of distilled water was added. The homogenate was stirred with a glass rod and filtered through Whatman No. 1 filter paper on a Buchner funnel with slight suction. The filtrate was transferred to a separatory funnel. The lower clear phase was drained into a 250-ml round-bottom flask and concentrated with a rotary evaporator at 40°C. The concentrated lipid extract was quantitatively transferred to a vial and made up to a final volume of 20 ml with chloroform. Aliquots (2 ml each) were evaporated in tared vials to constant weight under nitrogen to determine the lipid content. Butylated hydroxy toluene (BHT) at a concentration of 0.05% was added to the remaining lipid extract, and the extract was stored at –40°C for further analysis.

Fatty-acid content: Fatty-acid contents of the total lipid extracts were determined by saponification of 50–100 mg of lipid with 10% alcoholic KOH (3 ml) at 85°C for 20 minutes. After water (3 ml) was added, the nonsaponifiable material was thrice extracted with hexane. The residual soaps were acidified to pH 1.5, and the free fatty acids were thrice extracted with hexane. The extracts were pooled, dried in a tared vial, and the weight of fatty acids determined. The average results of triplicate analyses are reported for each species. These data were used to calculate the weights of individual fatty acids separated by gas chromatography.

Phospholipids: The method of Raheja et al. (1973) was used for phospholipid determination. Aliquots of fish lipid extracts containing 1–10 μg of lipid phosphorus were added to test tubes (15 x 125 mm) and the solvent was evaporated to dryness. Chloroform (0.4 ml) and chromo-genic solution (0.1 ml; Raheja et al., 1973) were added, and the tubes were heated at 100°C in a water bath for 75 seconds. When it was cool, chloroform (5 ml) was added and the tubes were shaken gently. After the solvent and aqueous layers were separated, the lower chloroform layer was recovered and the absorbance read at 710 nm in a spectrophotometer (Bausch and Lomb Model 700). Pure dipalmitoyl phosphatidylcholine (4.4% phosphorus) was used to construct a standard curve of absorbance plotted against lipid phosphorus.

Sterols: Sterols were quantified by gas-liquid chroma-tography. Aliquots of fish lipids (30 mg) were added to screw-capped test tubes, and cholestane (500 jug) was added as an internal standard. The solvent was removed under nitrogen, and the lipid was saponified at 85°C for 30 minutes, by using 3 ml of 10% potassium hydroxide in 70% aqueous ethanol, to which 0.2 ml of benzene had been added to ensure miscibility. Distilled water (3 ml) was added, and hexane (2 ml) was used to extract the nonsaponifiable materials (sterols, etc.). Three extractions, each with 2 ml of hexane, were carried out for 1 hour, 30 minutes, and 30 minutes, respectively, to achieve complete extraction of the sterols. Shorter extraction times resulted in incomplete recovery of cholestane and cholesterol. The hexane was evaporated to 300 /ul, and aliquots of this solution were used to determine sterol content and composition by gas-chromatog-raphy (Hewlett-Packard Model 5630A automated gas chromatograph). The paired chromatographic columns were stainless steel, 60 cm long, 3.5 mm ID and were packed with 3% OV-17 on 100-120 mesh Gas Chrom P support (Applied Science, State College, PA). The temperature of the column, injection port, and detector were 230°C, 270°C, and 300°C, respectively. Sterols were identified by matching the retention times with standard authentic sterols: cholesterol, cholestanol, stig-masterol, and sitosterol (Applied Science, State College, PA).

Since gas chromatographic analyses indicated that cholesterol comprised 99% of total sterols, the sterol content of each sample was quantified by comparing cholesterol-cholestane peak area ratios with those of preassayed standard mixtures of cholesterol and cholestane (Ishikawa et al., 1974).

Fatty-acid analyses: Fifteen mg of lipid material containing 1 mg of triheptadecanoin acid as internal standard was saponified for 5 minutes at 95°C with 1.0 ml 0.5N KOH in dry methanol. After neutralization with 0.7N HC1, 3 ml of 14% boron triflouride in methanol was added, and the mixture was heated for 5 minutes at 90°C to achieve complete methylation. The fatty-acid methyl esters were thrice extracted from this mixture with hexane and concentrated to 0.5 ml. Analyses by thin-layer chromatography showed that complete methylation was achieved, and quantification by gas chromatography revealed recovery rates of 96 ± 2 for methyl heptadecanoate.

Gas chromatography: The content and composition of fatty-acid methyl esters (FAME) were analyzed by Hewlett Packard Series 5831A automated gas chromatograph, which features dual columns, dual flame ionization detectors, and a multifunction digital processor housed in a keyboard-controlled instrument. The computer processor controls column temperatures, integrates peak area, and records peak retention times. The automatic injector eliminated tedious manual injection and ensured injection of constant volumes. The temperature of injection port and detector were 250°C and 300°C, respectively. Hydrogen, nitrogen, and air flow rates were 45, 40, and 240 ml/min., respectively.

To obtain complete resolution and quantification of all fatty acids, two separate column packings were used under different conditions. For routine analysis of methyl esters, stainless steel columns (1.9 metre long, 3 mm ID) packed with EGSS, 10% on Gas-Chrom P 100–120 mesh (Applied Science, State College, PA) was used. The temperatures of the columns were 200°C when operated isothermally or, when operated with temperature programming, were 170°C initially and programmed at 2°C/ min. to a final temperature of 210°C and held at this temperature until the end of the run. The EGSS column packing coupled with temperature programming achieved separation of all fatty acids except that there was overlapping of C18:3 with C20:1 and of C20:4 with C22:1. These fatty-acid peaks were separated and quantified by means of a column packing of Silar 10C (Supelco, Bellefonte, PA), 10% coated on Gas-Chrom Q, 100 mesh. Dual columns (3.8 m long, 1/8″ ID) were operated isothermally at 210°C or at a temperature programmed from 200°C to 240°C at 1°C per minute. This succeeded in separating the C18:3 from C20:1 and C20:4 from C22:1. Because C20:1 and C22:1 rarely exceeded 1.5% and 1.0% of total fatty acids, the Silar 10C columns were not used for all duplicate analyses.

Identification of Fatty Acids

Because the molecular weights were so close and various positional isomers were present, several procedures were used to identify the fatty-acid methyl esters (FAME) on chromatograms. Initially we constructed a retention timetable for all FAME probably present in freshwater fish, by means of which a quick identification of unknown chromatographic peaks was possible. First, data for the retention timetable (table 1) were obtained by determining the retention times of standard mixtures of pure FAME; 16:0, 16:1, 18:0, 18:1, 18:2ω6, 18:3ω3, 20:0, 20:1, 20:2ω6, 20:3ω3, 20:4ω6, 20:5ω3, 22:6ω and 24:1 (Nu-Chek Prep, Elysion, Minn.). Then, using a graphical procedure (Ackman, 1963a) that involved plotting the log of retention time against the chain length of homologous series of FAME, four parallel lines were obtained which related molecular structure to

Table 1. *Retention times of standard fatty-acid methyl esters* relative to methyl oleate*

Fatty-acid methyl ester	*Relative retention time*	*Fatty-acid methyl ester*	*Relative retention time*
12:0	0.20	20:0	1.44
13:0	0.26	20:1w9	1.62
14:0	0.33	20:2w9	1.84
14:1	0.36	20:3w9	2.09
15:0	0.42	20:3w6	2.40
15:1	0.50	20:3w3	2.72
16:0	0.53	20:4w6	2.72
16:1w7	0.62	20:4w3	3.15
16:2w7	0.70	20:5w3	3.57
17:0	0.67	22:0	2.42
17:1	0.80	22:1w9	2.82
18:0	0.86	22:3w6	4.03
18:1w9†	1.00	22:3w3	4.57
18:2w9	1.13	22:4w6	4.64
18:2w6	1.24	22:4w3	5.27
18:3w6	1.41	22:5w6	5.27
18:3w6	1.41	22:5w6	5.27
18:3w3	1.62	22:5w3	6.03
18:4w3	1.84	22:6w3	6.90
19:0	1.11	24:1w9	4.73
19:1	1.29	24.6w3	11.62

**Determined isothermally at 200°C, using EGSS-X liquid phase and conditions as described in methods.*
†*w - denotes position of double bond from methyl end of fatty acid.*

Table 2. *Area response factors of some fatty acid methyl esters**

Fatty-acid methyl ester	*Calibration factor* $\left(\frac{\text{weight \%}}{\text{area \%}}\right)$
14:0	0.98
16:0	0.95
16:1	0.94
18:0	1.02
18:1	0.99
18:2	1.03
18:3	1.06
20:0	1.01
20:1	1.00
20:2	1.01
20:4	1.00
22:1	1.01
24:1	1.09
22:6	1.05

**6′ EGSS-X column packed 4/6/76.*

retention times for homologues of saturated, monounsaturated, $w6$ diunsaturated, and $w3$ triunsaturated fatty acids. These lines permitted the tentative identification of unknown FAME whose retention times fell on these plots. In addition, separation factors (Ackman, 1963b) were calculated by dividing the retention time of one FAME by the lower retention time of an isomeric FAME of the same chain length. Constant separation factors are obtained for FAME with same chain length but differing in the number of double bonds, for example, C18:3, C18:2, C18:1 and C18:0.

By applying these procedures and using the two different liquid-phase column packings EGSS-X and Silar 10C, most of the FAME in freshwater fish species were identified.

Quantification of Fatty Acids

The areas of the peaks on the chromatograms were integrated electronically by the digital processor. However, because several factors may influence detector response (Sheppard et al., 1968), area response factors were determined by chromatographing known amounts of standard FAME and plotting peak area vs. weights injected. An internal standard, methyl heptadecanoate, was also used to obtain relative area response factors for the principal FAME in fish and to estimate quantities of individual FAME. Thus, peak areas obtained by triangulation were corrected for variations in detector response and the percent distribution of each FAME computed (table 2).

RESULTS AND DISCUSSION

The summarized data on proximate composition and sterol and phospholipid content are presented in table 3. The proximate data for bullhead, burbot, drum, yellow perch, and walleye are comparable to those of Thurston et al. (1959), whereas those for trout diverge appreciably. These discrepancies and those observed for the lipids may be caused by several variable environmental, dietary, and physiological factors (Stansby, 1970; Ackman, 1974; Exler et al., 1975) and significantly by the portion of fish analyzed (Kinsella et al., 1975).

The phospholipid content of fish muscle, which heretofore was stated to be around 0.5g per lOOg fish, ranged from 185mg to 872 mg per lOOg filet in freshwater fish. At low lipid levels, the phospholipid content of filets tended to increase as total lipid content of filet increased but rarely exceeded 600 mg/lOOg filet. This relationship was expressed approximately by the equation

$$Y = 85X + 274$$

where

Y = phospholipid mg/100g filet, and
X = total lipid g/100g filet.

The phospholipid content of the total lipid (fig. 1) decreased as the total extractable lipid increased, and this inverse relationship was best expressed by the equation

$$Y = .9728 + 27.724 \frac{1}{X}$$

where

Y = phospholipid as percent of total lipid, and
X = total lipid g/100g filet.

These data are useful for computing the fatty-acid content of fish lipids (Exler and Weihrauch, 1976). They also reveal that lean fish filets contain concentrations of phospholipids that could be of significance in the stability of filets, particularly since phospholipids

Table 3. *Summary data showing proximate composition, phospholipid and sterol content of representative samples of freshwater finfish filets*

Fish species: Common (Scientific)	Proximate composition: Moisture	Protein	Ash	Lipid	Phospholipid	Sterol	Triglyceride
	g/100g filet wet weight						
Bass, rock (*Ambloplites rupestris*) (3)	80.5 ± 0.8	17.8 ± 0.7	1.0 ± 0.1	0.7 ± 0.2	0.19	0.050	0.46
Bass, white (*Morone chrysops*) (5)	74.3 ± 0.8	20.2 ± 1.6	1.2 ± 0.1	3.8 ± 0.4	0.36	0.068	3.38
Bullhead, brown (*Ictalurus nebulosus*) (7)	78.5 ± 2.1	18.6 ± 0.3	1.1 ± 0.0	2.7 ± 0.3	0.64	0.075	1.99
Bubot (*Lota lota*) (6)	78.4 ± 1.5	20.7 ± 1.7	1.1 ± 0.0	0.7 ± 0.0	0.36	0.085	0.26
Carp (*Cyprinus carpio*) (2)	78.4	-	1.1	2.0	-	-	-
Crappie, black (*Pomoxis nigromaculatus*) (7)	78.0 ± 0.5	18.8 ± 0.3	1.1 ± 0.1	1.5 ± 0.8	0.27	0.072	1.16
Drum, freshwater (*Aplodinotus grunniens*) (6)	77.4 ± 1.9	18.0 ± 0.8	1.2 ± 0.1	3.2 ± 1.7	0.26	0.064	2.78
Perch, white (*Morone americanus*) (6)	77.5 ± 1.5	19.8 ± 0.2	1.2 ± 0.1	2.5 ± 1.2	0.30	0.080	1.92
Perch, yellow (*Perca flavescens*) (10)	79.1 ± 0.9	19.4 ± 0.1	1.1 ± 0.1	0.8 ± 0.1	0.40	0.090	0.32
Pike, northern (*Esox lucius*) (1)	79.8	-	-	0.7	-	-	-
Pike, walleye (*Stizostedion vitreum*) (7)	78.6 ± 0.7	19.5 ± 0.4	1.2 ± 0.1	1.1 ± 0.3	0.43	0.086	0.59
Smelt, American (*Osmerus mordax*) (18)	77.8 ± 1.3	18.3 ± 0.4	1.2 ± 0.1	2.2 ± 0.4	0.87	0.070	1.16
Sucker, white (*Catostomus commersonni*) (5)	78.6 ± 1.6	16.9 ± 1.3	1.2 ± 0.1	1.9 ± 0.2	0.47	0.063	1.37
Sunfish, pumpkinseed (*Lepomis gibbosus*) (8)	79.5 ± 0.6	19.4 ± 0.4	1.1 ± 0.1	0.7 ± 0.2	0.22	0.067	0.42
Trout, brook (*Salvelinus fontinalis*) (8)	74.3 ± 1.7	21.5 ± 0.5	1.3 ± 0.1	3.4 ± 1.2	0.61	0.068	2.72
Trout, lake (*Salvelinus namaycush*) (4)	72.4 ± 2.8	18.6 ± 0.4	1.1 ± 0.1	7.2 ± 2.6	-	0.051	-
Trout, rainbow (*Salmo gairdneri*) (6)	76.9 ± 1.2	18.8 ± 0.5	1.3 ± 0.0	3.1 ± 1.3	0.87	0.050	2.18

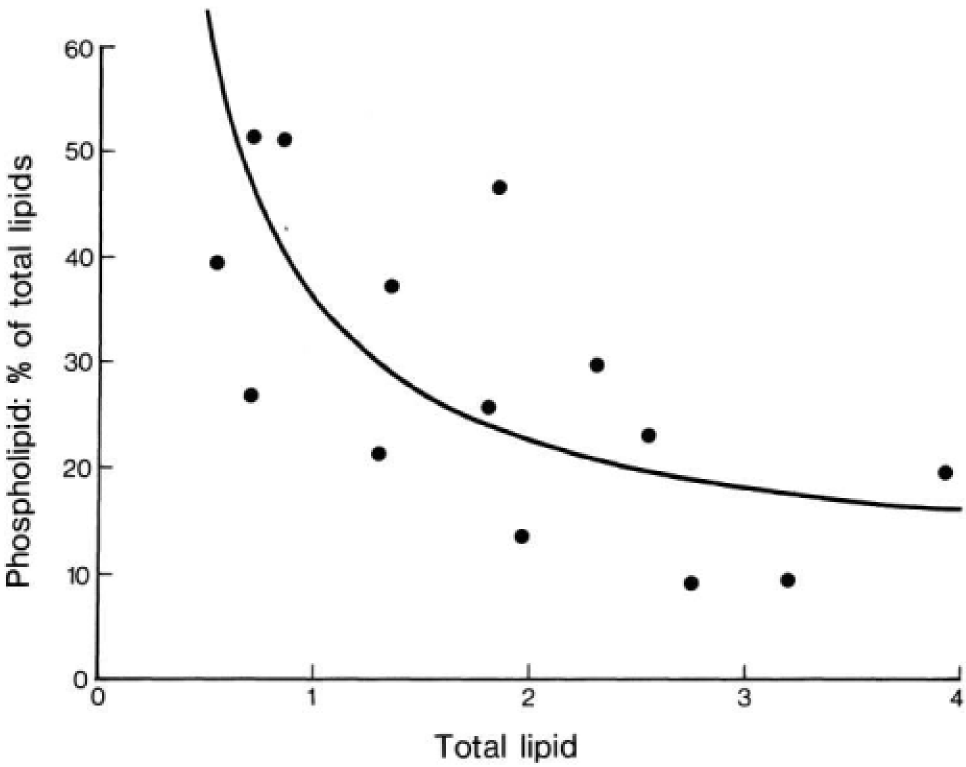

Figure 1. *A regression showing the inverse relationship between phospholipid levels in total lipid and total lipid content of freshwater fish filets.*

contain high levels of polyunsaturated fatty acids which are very susceptible to oxidative deterioration.

There is little information concerning the sterol content and composition of freshwater fish filets. Such information is important for dietary purposes, for example, in the use of fish as high-protein, low-fat, low-sterol, highly unsaturated (fatty acid) dietary items. The levels in filets are relatively low (table 3) and from gas chromatographic analyses, they were found to be preponderantly cholesterol. Moreover, the concentration of cholesterol in filets was reasonably constant, though the total lipid content varied markedly. The cholesterol concentration of the total lipids increased exponentially as lipid content of filets decreased (fig. 2), that is

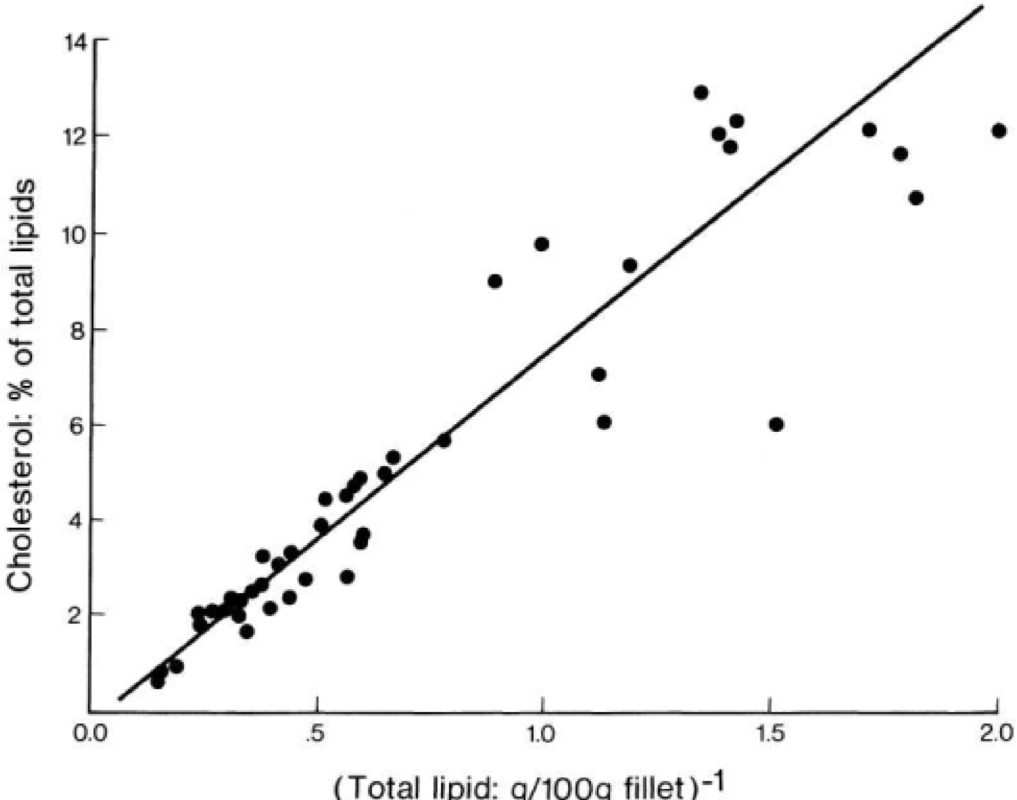

Figure 2. *A regression showing the relationship between cholesterol concentration and total lipid content of freshwater fish filets.*

$$Y = -.284 + 7.57 \frac{1}{X}$$

where

Y = percent cholesterol in lipids, and

X = total lipid g/100g filet.

These data should be useful for medical personnel and dieticians in formulating special diets for patients who require a low-fat regimen.

Table 4. *Examples of variations in size, sex, and lipid content of filets of some freshwater fish species*

Fish		*Weight*	*Whole fish* *Length*	*Sex*	*Lipid content*
		g	*cm*		*g/100g filet*
Perch, yellow	1	399	29.5	F	1.01
	2	303	27.6	M	1.07
	3	244	25.3	M	1.29
	4	241	24.4	M	1.10
Walleye	1	822	42.4	F	1.23
	2	702	42.6	F	1.01
	3	804	41.1	M	1.10
	4	557	39.4	F	0.80
	5	398	35.7	F	1.03
	6	330	32.5	F	0.97
Bullhead	1	581	35.2	M	2.82
	2	219	26.6	F	2.21
Pike, northern	1	1303	59.7	F	0.85
	2	883	53.5	M	0.91

Several analyses (table 4) revealed that there was no apparent correlation between size of fish, gender, and lipid content. The data obtained showed no definite relationship between fatty-acid composition and sex or size of a fish. However, carefully controlled experiments with large numbers of fishes would be required to establish the validity of these limited data.

In seeking the best sampling procedures, it was observed that lipid content and fatty-acid composition varied significantly with the portion of filet analyzed (table 5). Thus in lake trout, the ventral portions of the anterior segments of the filets contained higher lipid levels. The lipid content tended to decrease toward the tail section. The fatty-acid composition of the various sections varied slightly, with oleic acid (C18:l) tending to decrease, and docosahexaenoic acid (C22:6) to increase toward the posterior section. Because of this variation in lipid distribution, the filets of all fish species were cut into small portions (1 -2 cm^2) before each analysis. These pieces were mixed thoroughly and random samples were then taken and analyzed as described in the *Methods* section.

The fatty-acid content of the total lipids increased linearly as the lipid content of filets increased (fig. 3), which was consistent with the increasing triglycerides in these samples. This trend was discussed by Exler et al. (1975).

Table 5. *Lipid content and fatty-acid composition of lipids from representative sections of lake trout filet**

Fatty acid	*Section of filet*								
	1V	*1D*	*2V*	*2D*	*5V*	*5D*	*7*	*8*	*9*
14:0	4.1	3.6	4.3	4.3	3.3	3.4	3.8	3.8	3.4
16:0	15.5	14.9	15.8	16.0	17.7	15.0	15.0	16.0	16.9
16:1	7.8	6.8	8.0	6.8	7.9	7.0	7.8	7.9	7.2
18:0	3.6	4.0	3.9	3.7	3.3	3.0	4.0	4.4	3.7
18:1	24.7	27.6	24.6	24.1	23.6	29.5	23.3	23.2	22.0
18:2*w*6	4.9	8.3	4.6	4.6	5.1	4.6	4.4	4.7	4.0
18:3*w*3†	6.3	4.6	6.4	6.4	5.9	6.0	6.3	5.9	5.8
18:4*w*3	2.8	1.5	1.8	2.7	3.2	2.0	3.2	2.5	2.1
20:4*w*6‡	4.0	3.2	4.1	4.1	4.1	4.0	3.7	3.7	4.4
20:4*w*3	2.7	2.0	2.8	2.7	2.5	2.5	2.3	2.3	1.8
20:5*w*3	5.4	4.6	5.4	5.4	5.3	5.3	4.9	5.0	5.9
22:4*w*6	1.2	1.2	1.1	1.5	1.5	1.5	1.4	0.9	1.6
22:5*w*6	1.4	1.4	1.3	1.5	1.5	1.4	1.5	1.3	1.5
22:5*w*3	3.4	3.5	3.3	3.5	3.5	3.0	3.3	2.9	3.8
22:6*w*3	10.0	12.0	9.4	10.9	11.6	11.6	11.7	12.9	15.7
others§	2.2	0.8	3.2	1.8	0.2	1.0	3.4	2.6	0.2
Lipid content (%)	15.7	7.4	15.3	12.7	12.1	7.7	6.4	5.2	5.3

**Fish filets cut into 9 equal sections, moving from head to tail and designated 1 through 9. Some sections divided to ventral and dorsal tissues, designated as V and D, respectively.*
†*Includes 1.5–2.0% C20:1.*
‡Includes <1% C22:1.
§*Includes all fatty acids with weight % below 1 %.*

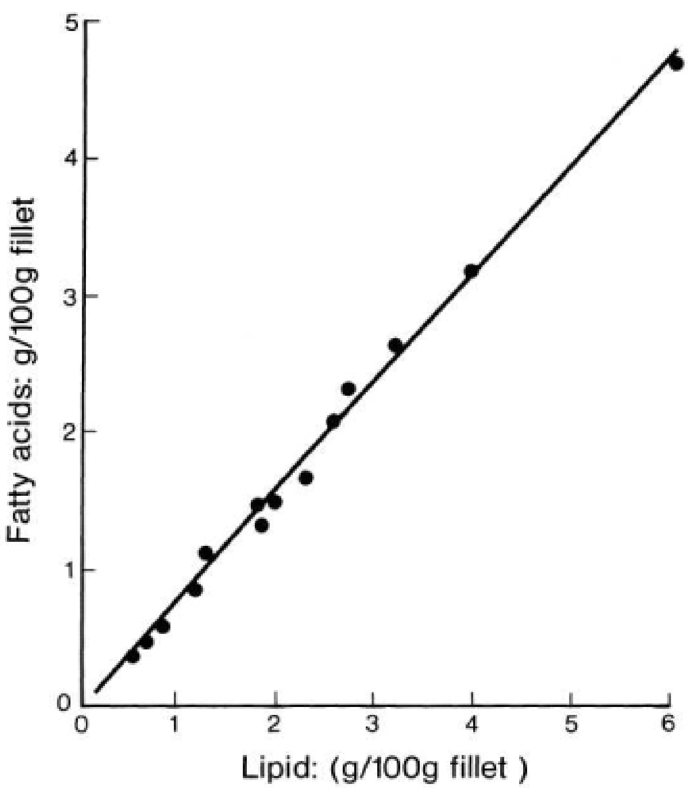

Figure 3. *Plot showing the close correlation between total fatty acid and lipid content of freshwater fish filets.*

Palmitic, palmitoleic, oleic, eicosapentaenoic (C20: 5*w*3), and docosahexaenoic (C22:6*w*3) were the major component fatty acids in all species analyzed (tables 9–26). Significant variations in distribution of various fatty acids were observed within and between species. The averaged data are shown in table 6, and the relative concentration of the various groups of fatty acids are summarized in table 7. The content of each fatty acid per 100g edible filet is shown in table 8.

The saturated fatty acids were remarkably constant in all species, at around 25 percent and palmitic was the predominant saturated acid in all species examined.

The fatty-acid composition of the various species revealed many interspecies differences (Summary table 6). Palmitic (C16:0), palmitoleic (C16:9), oleic (C18:1), excosapentaenoic (C20:5*w*3), and docosahexaenoic (C22:6*w*3) were the most abundant fatty acids in all species. There was no consistency in the predominance of any one fatty acid. In rock bass, yellow perch, and northern pike, C22:6 was predominant; in white perch, white bass, and drum C18:1; in white sucker, C16:1; and in sunfish and burbot, C16:0 was predominant. Both of these latter species had a high content of C20:4. The filets of brook and rainbow trout generally contained higher concentrations of 18 carbon polyunsaturated fatty acids, whereas the lake trout had high concentration of C18:1.

Table 6. *Average fatty-acid composition of total lipids from filets of several species of freshwater fish**

Fish species	C14:0	C16:0	C16:1w7	C18:0	C18:1w9	C18:w6	C18:3w3	C18:4w3
Bass, large-mouth (2)	2.6	18.6	9.3	3.5	17.6	3.0	3.1	1.3
Bass, rock (3)	2.4 ± 0.3	19.3 ± 0.6	9.0 ± 1.3	4.6 ± 0.4	17.8 ± 5.2	2.0 ± 0.1	2.1 ± 0.1	—
Bass, white (5)	2.6 ± 0.2	17.6 ± 0.8	11.4 ± 0.8	3.0 ± 0.5	29.5 ± 1.5	2.6 ± 0.4	3.3 ± 0.3	1.2 ± 0.2
Bullhead, brown (7)	2.4 ± 0.2	18.5 ± 1.6	13.8 ± 2.0	2.8 ± 0.7	25.7 ± 4.1	4.4 ± 1.5	5.4 ± 1.4	—
Burbot (6)	—	20.0 ± 0.8	3.8 ± 1.0	6.3 ± 0.6	15.9 ± 0.6	1.1 ± 0.2	tr	—
Crappie, black (6)	3.1 ± 0.8	20.3 ± 0.9	11.3 ± 2.7	3.3 ± 0.7	19.6 ± 5.1	3.1 ± 0.3	3.0 ± 0.7	1.1 ± 0.5
Drum, freshwater (6)	2.2 ± 0.4	19.5 ± 2.1	16.6 ± 3.0	3.3 ± 0.5	26.4 ± 5.9	3.1 ± 1.0	2.5 ± 2.0	—
Perch, white (6)	2.7 ± 0.3	18.9 ± 2.2	14.1 ± 2.4	3.1 ± 0.6	25.2 ± 1.7	3.6 ± 0.5	3.5 ± 0.5	1.9 ± 0.5
Perch, yellow (10)	2.0 ± 0.4	20.3 ± 1.2	7.9 ± 1.8	4.7 ± 0.7	9.1 ± 1.4	1.6 ± 0.3	1.7 ± 0.6	1.3 ± 0.5
Pike, northern (2)	2.1	16.2	5.9	3.8	12.7	4.0	3.0	—
Pike, walleye (7)	1.7 ± 0.2	18.9 ± 1.0	9.4 ± 1.7	3.3 ± 0.4	18.8 ± 3.0	2.5 ± 0.4	1.3 ± 0.2	—
Salmon (1)	2.9	10.7	5.0	3.6	24.5	5.2	5.3	1.5
Smelt (6)	4.6 ± 0.2	13.8 ± 0.3	9.0 ± 0.4	1.3 ± 0.1	17.5 ± 1.2	3.6 ± 0.3	4.5 ± 0.2	1.7 ± 0.2
Sucker, white (5)	2.5 ± 0.7	15.3 ± 1.0	18.8 ± 2.4	2.2 ± 0.6	14.3 ± 2.1	2.7 ± 0.7	2.3 ± 0.6	1.9 ± 0.3
Sunfish, pumpkinseed (8)	2.3 ± 0.7	18.8 ± 1.3	7.9 ± 2.5	5.3 ± 0.7	13.2 ± 3.0	2.9 ± 0.6	1.9 ± 0.8	—
Trout, brook (8)	3.7 ± 0.2	17.9 ± 1.2	11.2 ± 2.4	4.0 ± 0.4	21.2 ± 3.5	5.5 ± 0.6	6.0 ± 0.6	2.8 ± 0.6
Trout, lake (4)	3.4 ± 0.2	13.4 ± 0.9	9.6 ± 1.6	2.7 ± 0.4	29.0 ± 2.3	3.6 ± 0.5	2.9 ± 0.4	1.1 ± 0.3
Trout, rainbow (6)	3.5 ± 0.4	13.3 ± 0.5	4.8 ± 0.9	3.8 ± 0.4	18.7 ± 2.7	5.5 ± 0.4	5.9 ± 0.5	2.1 ± 0.4

Fish species	C20:1w9	C20:4w6	C20:4w3	C20:5w6	C22:4w6	C22:5w6	C22:5w3	C22:6w6
Bass, large-mouth (2)	2.0	5.1	1.0	5.0	1.9	1.5	4.5	16.7
Bass, rock (3)	—	8.4 ± 2.8	—	4.3 ± 1.1	—	1.8 ± 0.3	3.6 ± 0.0	20.7 ± 3.2
Bass, white (5)	1.7	4.3 ± 0.3	—	7.1 ± 0.5	—	1.1 ± 0.1	1.4 ± 0.1	10.6 ± 0.8
Bullhead, brown (7)	1.1	4.9 ± 0.9	—	7.2 ± 1.9	—	—	2.4 ± 0.9	7.0 ± 1.2
Burbot (6)	—	15.8 ± 2.0	—	12.0 ± 1.5	1.1 ± 0.1	1.5 ± 0.3	2.8 ± 0.3	17.1 ± 2.7
Crappie, black (6)	—	5.6 ± 1.8	—	4.8 ± 1.6	—	1.4 ± 0.3	4.6 ± 0.7	14.7 ± 4.6
Drum, freshwater (6)	1.2 ± 0.4	4.9 ± 2.9	—	5.1 ± 1.4	—	1.1 ± 0.9	2.2 ± 0.6	6.9 ± 4.2
Perch, white (6)	1.1 ± 0.0	5.1 ± 1.0	—	10.6 ± 0.9	—	—	1.5 ± 0.2	3.6 ± 1.5
Perch, yellow (10)	—	7.7 ± 1.1	—	11.5 ± 0.9	1.2 ± 0.4	1.7 ± 0.4	2.5 ± 0.4	26.4 ± 2.0
Pike, northern (2)	—	7.5	—	6.1	1.1	1.3	3.4	30.7
Pike, walleye (7)	—	5.6 ± 1.3	—	8.2 ± 0.8	—	1.8 ± 0.3	1.8 ± 0.3	21.6 ± 2.7
Salmon (1)	1.0	5.3	2.3	4.5	2.2	2.3	5.0	17.0
Smelt (6)	—	3.5 ± 0.3	—	13.3 ± 1.0	—	1.1 ± 0.1	—	22.5 ± 1.8
Sucker, white (5)	1.2 ± 0.2	4.3 ± 0.4	—	10.3 ± 2.8	—	—	3.4 ± 0.3	14.9 ± 1.3
Sunfish, pumpkinseed (8)	1.0 ± 0.2	14.9 ± 2.9	—	7.1 ± 1.9	1.4 ± 0.2	3.0 ± 0.5	3.3 ± 0.5	13.7 ± 2.5
Trout, brook (8)	—	4.3 ± 0.4	1.0 ± 0.3	7.1 ± 0.9	—	—	1.6 ± 0.2	9.3 ± 2.8
Trout, lake (4)	2.1 ± 0.3	3.8 ± 0.5	1.5 ± 0.3	5.0 ± 0.7	—	1.8 ± 0.3	2.9 ± 0.2	13.4 ± 1.2
Trout, rainbow (6)	—	4.4 ± 0.3	2.8 ± 0.3	5.1 ± 0.6	—	2.5 ± 0.5	3.7 ± 0.2	21.0 ± 5.3

**Number of fish analyzed given in parentheses. Fatty acids amounting to less than 1% not included.*
Sucker contained 1.7% C17:1; the C20:4 contains less than 1% C22:1.

Table 7. *Relative concentrations of different groups of fatty acids in freshwater fish filets*

Species	*Saturated acids*	*Unsaturated species of fatty acids*						*Families of fatty acids*			
		Number of double bonds									
		1	*2*	*3*	*4*	*5*	*6*	*w3*	*w6*	*w7*	*w9*
					weight percent						
Bass, large mouth (2)	23.7	29.0	3.0	3.1	7.3	10.0	16.7	31.6	11.5	9.3	19.6
Bass, rock (3)	26.3	26.8	2.0	2.1	8.4	9.7	20.7	30.7	12.2	9.0	17.8
Bass, white (5)	23.2	42.6	2.6	3.3	4.3	9.5	10.6	23.6	3.7	11.4	29.5
Bullhead (7)	23.7	30.6	4.4	5.4	5.0	9.6	7.0	22.0	9.3	13.8	26.8
Burot (6)	26.3	19.7	1.1	tr	16.9	16.3	17.1	28.0	19.5	3.8	16.0
Crappie (6)	27.7	30.9	3.1	3.0	6.7	10.8	14.7	28.2	10.1	11.3	19.6
Drum (6)	25.0	44.2	3.1	2.5	5.0	8.3	7.0	16.7	9.1	16.6	27.6
Perch, white (6)	26.7	40.4	3.6	3.5	7.0	12.1	3.6	21.1	8.7	14.1	26.3
Perch, yellow (10)	27.0	17.0	1.6	1.7	10.2	14.7	26.4	43.5	11.0	7.9	9.1
Pike, northern (1)	22.1	18.6	4.0	3.0	8.6	10.9	30.7	42.9	12.8	6.0	12.7
Pike, walleye (7)	23.9	28.2	2.5	1.3	5.6	11.8	21.6	33.0	10.0	9.4	18.8
Salmon (1)	17.2	29.5	5.2	5.3	13.3	11.5	17.0	35.6	15.0	5.0	25.5
Smelt (6)	19.8	26.5	3.6	4.5	5.2	14.4	22.5	42.0	8.2	9.0	17.5
Sucker (5)	21.2	33.1	2.7	2.3	6.2	13.7	15.0	32.8	7.0	18.8	15.5
Sunfish (3)	27.4	21.1	2.9	2.0	16.4	13.4	13.7	26.0	19.4	8.0	14.0
Trout, brook (8)	25.6	32.4	5.5	6.0	8.1	8.6	9.3	27.8	9.8	11.2	21.2
Trout, lake (4)	19.5	40.6	3.6	2.9	6.4	9.5	13.4	27.0	9.2	9.6	31.1
Trout, rainbow (6)	20.6	23.5	5.5	6.0	9.3	11.3	21.0	41.6	9.9	4.8	18.7

w - denotes position of first double bond from methyl end of the fatty acid.

Table 8. *Concentration of individual fatty acids in fillets of several species of freshwater fish*

Fish species	Fatty acids																	
	C14:0	C16:0	C16:1	C17:1	C18:0	C18:1	C18:2	C18:3	C18:4	C20:1	C20:4 w6	C20:4 w3	C20:5	C22:4	C22:5 w6	C22:5 w3	C22:6	Total
	mg/100g fillet																	
Bass, rock	12	97	45	-	23	89	10	11	-	-	42	-	22	-	9	18	104	500
Bass, white	81	547	355	-	93	918	81	103	37	44	134	-	221	-	34	44	330	3110
Bullhead, brown	51	390	291	-	59	542	93	114	-	23	103	-	152	-	-	51	148	2110
Barbot	-	96	18	-	30	76	5	-	-	-	76	-	58	5	7	13	82	480
Crappie, black	37	242	135	-	39	233	37	36	13	-	67	-	57	-	17	55	175	1190
Drum, freshwater	58	513	437	-	87	694	82	66	-	32	129	-	134	-	29	58	182	2630
Perch, white	42	291	217	15	48	388	55	54	29	17	79	-	163	-	-	23	55	1540
Perch, yellow	11	108	42	-	25	48	9	9	7	-	41	-	61	6	9	13	140	530
Pike, walleye	13	147	73	-	26	147	20	10	-	-	44	-	64	-	14	14	169	780
Smelt	70	211	138	18	20	268	55	69	26	-	54	-	204	-	17	-	344	1530
Sucker, white	39	237	291	23	34	222	42	36	30	19	67	-	160	-	-	53	231	1550
Sunfish, pumpkinseed	11	90	38	-	25	63	14	6	-	5	72	-	34	7	14	16	66	480
Trout, brook	100	482	301	-	108	570	148	161	75	-	116	27	191	-	-	43	250	2690
Trout, lake	192	758	543	-	153	1641	204	164	62	119	215	85	283	-	102	164	758	5660
Trout, rainbow	78	298	108	-	85	419	123	132	47	-	99	63	114	-	56	83	470	2240

Table 9. *Proximate, lipid, and fatty acid composition of filets from samples of bass, rock* (Ambloplites rupestris)

Fish No.	*J120*	*F121*	*F122*	Avg.
Weight (g)	392	276	209	
Length (mm)	251	226	206	
Filet weight (g)	74	85	61	
Moisture (%)	81.3	80.5	79.7	80.5
Lipid (%)	0.5	0.7	0.9	0.7
Protein (%)	17.3	17.6	18.6	17.8
Ash (%)	1.1	1.0	1.0	1.1
				100.1%
Fatty acid (%)				
14:0	2.26	2.31	2.75	
16:0	18.99	20.01	18.89	
16:1	8.34	8.18	10.47	
18:0	4.67	4.91	4.22	
18:1	15.27	14.34	23.75	
18:2w6	2.15	1.98	2.01	
18:3w3	1.99	2.19	2.24	
18:4w3	0.51	0.46	0.54	
20:0	0.14	0.26	0.22	
20:1	-	-	-	
20:2	0.48	0.23	0.19	
20:3	-	0.23	-	
20:4w6	11.43	7.95	5.84	
20:4w3	0.33	0.35	0.25	
20:5w3	5.46	4.25	3.25	
22:4w6	0.81	0.83	0.74	
22:5w6	1.92	1.95	1.47	
22:5w3	3.62	3.62	3.68	
22:6w3	19.96	24.21	17.90	
Fatty acid (% of total lipid)	66.4	70.6	72.8	
Sterols (%)	10.6	5.9	6.0	

Table 10. *Proximate, lipid, and fatty-acid composition of filets from samples of bass, white* (Morone chrysops)

Fish no.	*F46*	*F112*	*F113*	*F114*	*F115*	Avg.
Weight (g)		409	507	425	424	
Length (mm)		294	305	294	297	
Filet weight (g)		121	140	149	159	
Moisture (5)	74.8	73.0	75.0	-	74.6	74.3
Lipid (%)	3.7	3.7	3.5	4.6	3.5	3.8
Protein (%)	19.1	-	19.6	-	22.0	20.2
Ash (%)	-	-	1.1	-	1.2	1.2
						99.5%
Fatty acid (%)						
14:0	2.5	2.29	2.68	2.76	2.86	
16:0	17.9	16.94	17.29	17.17	18.87	
16:1	11.9	10.22	11.73	12.21	11.12	
18:0	2.8	3.45	2.50	2.70	3.59	
18:1	28.3	31.55	28.03	28.92	30.46	
18:2w6	2.1	2.62	3.16	2.55	2.37	
18:3w3	3.3	3.15	3.65	3.46	2.95	
18:4w3	1.3	0.89	1.16	1.37	1.48	
20:0	0.4	0.28	0.34	0.26	0.30	
20:1	1.7	-	-	-	-	
20:2	0.3	0.22	0.22	0.14	0.05	
20:3	-	-	-	-	-	
20:4w6	3.9	4.63	4.63	4.22	4.02	
20:4w3	0.4	0.33	0.39	0.37	0.46	
20:5w3	7.5	6.35	7.40	7.11	6.89	
22:4w6	0.7	0.43	0.42	0.46	0.42	
22:5w6	1.1	1.24	1.22	1.15	0.90	
22:5w3	1.5	1.33	1.36	1.36	1.25	
22:6w3	10.5	11.46	10.79	10.89	9.32	
17:1	0.7	-	-	-	-	
22:1	0.5	-	-	-	-	
Fatty acid (%) of Total lipid)	82.2	-	82.0	-	82.0	
Sterols (%)	2.1	-	2.3	-	2.0	

During biosynthesis of unsaturated acids, in vivo, de-saturation occurs between the initial double bond and the carboxyl group, and elongation also occurs at the carboxyl end. Unsaturated fatty acids in fish can be categorized into four families, according to the location (denoted by omega — *w)* of the first double bond from the methyl end of the hydrocarbon chain, that is, *w7,*

Table 11. Proximate, lipid, and fatty-acid composition of fillets from samples of bullhead, brown (Ictalurus nebulosus)

Fish no.		*87*	*88*	*89*	*90*	*91*	*92*	
Weight (g)	603	373	588	125	487	279	682	
Length (mm)	317	273	320	203	317	250	340	
Filet weight (g)	161	873	169	253	137	84	231	Avg.
Moisture (%)	76.4	76.8	81.2	-	78.1	77.7	81.0	78.5
Lipid (%)	3.2	2.3	2.7	-	2.6	2.8	2.8	2.7
Protein (%)	-	18.3	-	-	18.9	18.7	-	18.7
Ash (%)	-	1.1	-	-	1.1	1.1	-	1.1
Fatty acid (%)								101%
14:0	2.3	2.51	2.72	2.16	2.39	2.07	2.43	
16:0	20.0	18.79	20.15	15.28	18.22	18.23	18.79	
16:1	13.2	14.46	14.73	9.81	15.50	13.01	15.75	
18:0	3.5	2.40	2.09	4.02	2.56	2.61	2.68	
18:1	29.1	24.82	27.53	17.15	26.92	25.86	28.78	
18:2w6	3.5	4.73	3.09	7.02	3.27	5.66	3.73	
18:3w3	3.6	5.25	3.09	6.37	3.14	6.08	4.66	
18:4w3	0.5	0.31	0.44	0.29	1.02	0.35	0.74	
20:0	0.5	-	-	-	-	-	-	
20:1	1.1	-	-	-	-	-	-	
20:2	0.1	0.33	-	0.83	-	0.59	0.18	
20:3	0.1	0.19	-	0.59	-	0.32	0.23	
20:4w6	4.4	4.81	4.78	6.56	4.65	5.07	3.75	
20:4w3	0.4	0.42	0.54	0.76	0.53	0.47	0.49	
20:5w3	5.4	8.38	6.22	10.83	7.30	7.02	5.54	
22:4w6	0.4	0.47	0.81	0.86	0.86	0.85	0.54	
22:5w6	0.8	0.32	0.82	0.58	0.72	0.45	0.54	
22:5w3	1.8	2.56	1.79	4.26	2.36	2.34	1.88	
22:6w3	6.1	6.48	8.42	8.82	7.37	5.54	6.48	
Fatty acid (% of total lipid)	-	76.6	-	-	75.2	82.0	-	
Sterols (%)	-	3.1	-	-	2.6	3.2	-	

palmitoleic; w9, oleic; w6, linoleic; and w3, linolenic, respectively. The concentrations of fatty acids of these families in freshwater fish vary, but usually fatty acids of the w3 family, composed mostly of 20:5w3 and C22:6w3 (which are derived by elongation and desaturation of C18:3w3), are most abundant, with the w9 series usually ranking second in abundance. Compared with marine species of fish (Ackman, 1974), freshwater fish usually contain higher levels of w6 series — the essential fatty acids. All species of freshwater fish (table 7) contained significant quantities of the w6 series, particularly C18:2 and C20:4. The presence of these and the other polyunsaturated acids emphasizes the potential of freshwater fish for use in special low-fat diets as postulated by Stansby (1973). The w3 fatty acids, specifically C22:6, have been indirectly implicated in the prevention of multiple sclerosis (Stansby, 1969).

With regard to groups of fatty acids (table 7), the monoenoic acids were quite variable, ranging from 17 to 44 percent in the yellow perch and drum, respectively. Oleic acid was the major monounsaturated fatty acid. Dienoic and trienoic acids occurred at a low but consistent concentration, each averaging around 3 percent of total fatty acids. Freshwater finfish characteristically have more of these acids than marine species (Ackman, 1967b). The polyunsaturated fatty acids showed broad variations. Tetraenoid species, consisting mostly of arachidonic acid (C20:4), were highest in burbot, sunfish, and salmon. The concentration of pentaenoic acids was reasonably constant around 9 to 10 percent except burbot, perch, sunfish, and smelt. The hexaenoic acids, exclusively C22:6, fluctuated widely from species to species ranging from a low of 3.6 percent in white perch to 30.7 percent in northern pike. The levels of pentaenoic and hexaenoic acids observed in this study greatly exceeded those observed by Ackman (1967b) for a limited number of species.

The fatty-acid composition of the freshwater fish reported here show marked differences in quantities of polyunsaturated fatty acids, especially C22:6, compared to various European species analyzed by Mangold (1973).

Comparison of the fatty-acid composition (tables 9-26) with other published data is of limited value because of the numerous factors which can affect both lipid content and fatty-acid composition of fish, i.e. origin, age, sex, diet, physiological state, season, geographical source, portion analyzed, etc. (Kinsella et al., 1975; Exler et al., 1975; Ackman, 1967b, 1974; Stansby, 1969; Worthington and Lovell, 1973; Reiser et al., 1963).

Interspecies variation in fat content and composition of freshwater fish has been summarized by Ackman (1967), who reviewed the numerous studies showing effects of location of catch, age, size, temperature, and diet on these components. Worthington and Lovell (1973) concluded that within cultured carp species the observed variations in fatty acids attributable to genotype were small but significant. The major differences were attributed to dietary factors.

The apparent discrepancies between the present and much of the published data on the same species may be explained by the fact that our data pertain solely to skinned filets rather than to whole fish or fish filets with skin. Many fishes store triglycerides in the liver, and several that store triglycerides in the muscle deposit it in a layer beneath the skin (Ackman, 1974; Stansby, 1973). Thus, differences in published data may also be traced to the portion of the fish analyzed. In this study, the filets analyzed contained low quantities of triglycerides and relatively high proportions of phospholipids (Kinsella et al., 1977). This may account to some extent for the higher concentrations of polyenoic fatty acids found, since phospholipids usually contain significantly higher levels of unsaturated acids.

While knowledge of fatty-acid composition per se is useful for comparative purposes, the actual quantities of individual fatty acids must be known for nutritional evaluation. These values are shown in table 8. These data show that the relative concentration of dietary essential fatty acids is adequate if fish filets are the sole source of essential fatty acid in a particular diet.

Table 12. *Proximate, lipid, and fatty-acid composition of filets from samples of burbot* (Lota lota)

Fish no.	*F75*	*F76*	*F123*	*F124*	*F125*	*F126*	Avg.
Weight (g)	655	842	513	735	482	238	
Length (mm)	435	467	375	460	400	285	
Filet weight (g)	144	156	186	128	98	53	
Moisture (%)	78.6	80.6	76.0	78.4	78.2	78.3	78.4
Lipid (%)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Protein (%)	-	-	22.7	19.8	19.7	-	20.7
Ash (%)	-	-	1.1	1.1	1.1	-	1.1
							100.9%
Fatty acid (%)							
14:0	1.1	0.8	0.70	0.61	0.94	0.68	
16:0	21.2	20.3	20.18	21.07	19.12	19.69	
16:1	5.8	4.8	3.97	3.44	3.62	3.05	
18:0	6.9	7.3	6.15	6.17	5.86	6.95	
18:1	16.4	16.7	15.60	15.98	16.64	15.31	
18:2ω6	1.1	0.9	0.99	1.13	1.44	0.96	
18:3ω3	1.0	0.7	0.76	0.70	1.05	0.90	
18:4ω3	-	-	0.19	0.03	0.32	0.24	
20:0	0.4	0.4	0.19	0.05	0.23	0.18	
20:1	0.4	0.3	-	-	-	-	
20:2	-	-	-	-	-	-	
20:3	0.1	0.1	0.15	0.07	0.19	0.13	
20:4ω6	17.5	18.7	18.60	16.08	15.52	13.14	
20:4ω3	-	-	-	-	0.11	0.18	
20:5ω3	10.4	9.9	11.55	10.19	13.21	13.00	
22:4ω6	0.5	0.5	1.05	1.31	1.12	0.77	
22:5ω6	0.9	1.2	1.54	1.67	1.38	1.59	
22:5ω3	2.3	2.6	2.40	2.89	3.03	2.84	
22:6ω3	13.0	13.8	15.72	18.20	14.52	19.77	
Fatty acid (% of total lipid)	-	-	68.0	69.8	64.5	-	
Sterols (%)	-	-	12.0	12.3	11.7	-	

Table 13. *Proximate, lipid, and fatty-acid composition of filets from samples of crappie, black* (Pomoxis nigromaculatus)

Fish no.	*F73*	*93*	*94*	*95*	*96*	*97*	Avg.
Weight (g)	293	153	202	196	173	169	
Length (mm)	222	199	227	216	187	195	
Filet weight (g)	109	55.6	60.1	67	51	58	
Moisture (%)	78.4	78.5	77.9	77.3	77.6	78.2	78.0
Lipid (%)	1.8	1.5	1.5	2.9	0.6	0.9	1.5
Protein (%)	-	19.0	18.9	-	-	18.4	18.8
Ash (%)	-	1.1	1.0	-	-	1.2	1.1
							99.4%
Fatty acid (%)							
14:0	3.3	3.57	3.71	3.63	1.75	2.74	
16:0	21.5	18.93	19.78	19.90	20.91	20.75	
16:1	11.9	12.77	12.93	14.09	6.57	9.80	
18:0	4.3	2.67	2.78	2.96	3.96	3.34	
18:1	27.0	18.04	18.47	24.33	13.17	16.60	
18:2ω6	3.0	3.27	3.65	2.71	2.99	3.20	
18:3ω3	3.1	4.24	4.36	3.34	2.71	3.11	
18:4ω3	0.6	1.72	1.66	1.37	0.73	0.76	
20:0	-	-	-	-	-	-	
20:1	0.5	-	-	-	-	-	
20:2	-	-	-	-	-	-	
20:3	0.1	-	-	-	-	-	
20:4ω6	4.2	5.60	4.99	3.60	8.30	7.16	
20:4ω3	0.4	0.49	0.28	0.67	0.61	0.58	
20:5ω3	2.5	5.17	4.88	3.79	7.10	5.32	
22:4ω6	0.5	0.76	0.72	0.55	0.94	1.02	
22:5ω6	1.4	1.31	1.17	0.94	1.76	1.66	
22:5ω3	3.5	4.79	4.66	4.14	5.56	4.69	
22:6ω3	9.8	13.61	13.34	11.38	22.03	18.10	
Fatty acid (% of (total lipid)	-	74.4	75.4	80.8	-	-	
Sterols (%)	-	5.2	4.9	-	-	7.1	

Conclusions

Overall, these data show that the fatty acids of freshwater fish are highly unsaturated, with a high concentration of C20:5 and C22:6 fatty acids. Appreciable interspecies variation occurs in the fatty acids of freshwater finfishes. Nevertheless, from a nutritional standpoint, filets from these fish should be excellent for persons on special high-protein, low-calorie diets that should have a relatively high, polyunsaturated fatty-acid content.

Research Needs

The data indicate that filets of these fish may be very susceptible to oxidative deterioration and off-flavor development during storage. Further research is warranted to develop methods to improve preservation techniques.

There is negligible information concerning the effects of processing and cooking on fish lipids. This deficiency is of concern because the preponderance of fish consumed in the United States is in cooked or processed form. Furthermore, data on the lipids and sterols in processed fish products (fish sticks, fish portions, fish dinners) are not available despite the fact that these are common consumer items. Breading and deepfat frying of fish filets may significantly alter the fatty acid and sterol content and composition of edible fish, and this phenomenon needs to be studied in detail under different cooking methods and conditions.

Table 14. *Proximate, lipid, and fatty-acid composition of filets from samples of drum, freshwater* (Aplodinotus grunniens)

Fish no.	*F53*	*F54*	*F55*	*109*	*110*	*111*	Avg.
Weight (g)	170	1234	1371	721	616	691	
Length (mm)	190	405	430	340	323	345	
Filet weight (g)	37.5	370	509	244	147	222	
Moisture (%)	80.2	78.0	74.9	76.2	76.8	78.4	77.4
Lipid (%)	0.8	3.2	6.1	3.6	2.8	2.4	3.1
Protein (%)	-	17.1	-	-	18.7	18.2	18.0
Ash (%)	-	1.2	-	-	1.1	1.2	1.2
							99.7%
Fatty acid (%)							
14:0	1.4	2.2	2.5	2.35	2.45	2.27	
16:0	15.6	21.3	19.1	20.33	20.22	20.56	
16:1	10.6	17.5	18.2	18.12	18.07	17.03	
18:0	4.0	2.9	2.7	3.08	3.65	3.41	
18:1	15.5	29.1	33.0	28.01	26.76	26.20	
18:2ω6	2.5	2.0	2.6	3.15	4.71	3.66	
18:3ω3	1.8	1.7	2.2	4.48	6.36	5.34	
18:4ω3	-	0.5	0.8	0.68	0.72	0.65	
20:0	0.2	0.2	0.4	0.25	0.32	0.34	
20:1	1.7	1.0	1.0	-	-	-	
20:2	0.7	0.2	0.3	-	-	0.07	
20:3	0.7	0.2	0.3	-	-	0.20	
20:4ω6	10.8	4.5	3.3	3.87	3.27	3.75	
20:4ω3	0.6	0.5	0.6	0.41	0.44	0.49	
20:5ω3	7.6	4.6	3.4	4.99	4.75	5.49	
22:4ω6	1.9	1.0	0.7	0.74	0.50	0.73	
22:5ω6	2.9	0.9	0.6	0.79	0.46	0.77	
22:5ω3	3.4	2.2	1.9	1.96	1.73	2.26	
22:6ω3	15.2	6.0	5.2	5.63	3.55	5.49	
Fatty acid (% of total lipid)	-	80.8	-	-	84.4	85.2	
Sterols (%)	-	2.3	-	-	2.5	2.1	

Table 15. *Proximate, lipid, and fatty-acid composition of filets from samples of perch, white* (Morone americanus)

Fish no.	*F71*	*F72*	*F116*	*F117*	*F118*	*F119*	Avg.
Weight (g)	264	243	338	238	187	357	
Length (mm)	225	232	256	230	220	274	
Filet weight (g)	73	71	117	72	66	128	
Moisture (%)	79.2	79.2	75.5	76.3	77.8	76.7	77.5
Lipid (%)	2.4	1.7	5.1	2.0	1.6	2.3	2.5
Protein (%)	-	19.5	-	-	20.0	20.0	19.8
Ash (%)	-	1.1	-	-	1.2	1.3	1.2
							101%
Fatty acid (%)							
14:0	2.9	2.4	3.22	2.55	2.43	2.73	
16:0	20.1	20.3	17.90	20.25	19.84	14.74	
16:1	13.4	11.4	16.84	13.26	12.56	17.32	
18:0	3.5	3.8	2.24	3.00	3.55	2.52	
18:1	26.1	23.9	28.24	25.15	23.82	24.08	
18:2ω6	3.6	3.9	3.99	2.91	3.18	4.08	
18:3ω3	5.1	3.9	4.49	4.20	4.41	5.51	
18:4ω3	1.4	1.3	2.52	1.82	1.82	2.53	
20:0	-	-	0.47	0.44	0.51	0.46	
20:1	1.1	1.1	-	-	-	-	
20:2	-	0.2	-	-	-	-	
20:3	0.1	0.1	-	-	-	-	
20:4ω6	5.1	6.2	3.40	4.94	5.76	5.13	
20:4ω3	0.4	0.4	0.62	0.66	0.72	0.76	
20:5ω3	9.4	10.2	9.85	11.33	11.10	11.75	
22:4ω6	0.2	0.4	-	0.40	0.41	0.44	
22:5ω6	0.5	0.7	0.10	0.55	0.55	0.39	
22:5ω3	1.3	1.6	1.34	1.56	1.69	1.43	
22:6ω3	3.4	5.2	1.03	3.94	4.76	3.00	
Fatty acid (% of total lipid)	-	75.8	-	76.6	-	76.8	
Sterols (%)	-	4.6	-	4.4	-	3.3	

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Table 16. *Proximate, lipid, and fatty-acid composition of filets from samples of perch, yellow* (Perca flavescens)

Fish no.	*77*	*78*	*79*	*80*	*81*	*82*	*83*	*84*	*85*	*86*	Avg.
Weight (g)	332	254	207	175	146	167	110	107	134	89	
Length (mm)	255	240	220	225	205	215	190	200	205	193	
Filet weight (g)	141.5	86.6	77.7	67.1	58.1	68.3	40.6	28.6	30.4	25.5	
Moisture (%)	78.5	78.0	80.6	79.3	80.1	79.1	78.1	79.4	78.2	79.2	79.1
Lipid (%)	0.9	1.0	0.7	0.8	0.7	0.7	0.9	0.7	0.8	0.6	.8
Protein (%)	19.3	-	-	19.5	-	19.3	-	-	-	-	19.4
Ash (%)	1.1	-	-	1.1	-	1.2	-	-	-	-	1.1
Fatty acid (%)											100.4%
14:0	2.09	1.71	2.36	2.63	2.42	1.54	1.87	1.49	1.47	2.41	
16:0	21.07	22.62	20.23	20.14	20.82	20.15	19.51	18.82	19.68	18.19	
16:1	9.04	8.70	8.63	9.80	9.73	5.82	8.25	5.08	5.43	7.50	
18:0	3.84	3.88	4.31	4.01	4.41	5.29	4.86	5.56	5.37	5.13	
18:1	9.32	12.57	8.44	8.36	10.19	8.23	8.96	7.91	8.03	8.40	
18:2w6	1.22	1.61	1.17	1.56	2.03	1.23	1.78	1.59	1.66	2.07	
18:3w3	1.87	0.85	2.23	2.86	2.01	1.56	2.38	1.84	2.04	2.60	
18:4w3	0.96	0.55	1.64	2.21	1.39	0.85	1.73	0.96	0.93	1.87	
20:0	-	-	-	-	-	-	-	-	-	-	
20:1	-	-	-	-	-	-	-	-	-	-	
20:2	-	-	-	-	-	-	-	-	-	-	
20:3	-	-	-	-	-	-	-	-	-	-	
20:4w6	7.44	5.76	7.25	7.00	6.74	8.18	7.36	9.31	8.96	8.27	
20:4w3	-	-	-	-	-	-	-	-	-	-	
20:5w3	10.85	9.64	11.90	12.23	11.33	11.86	11.35	13.00	10.58	11.26	
22:4w6	0.97	0.79	0.99	0.81	1.04	1.34	1.24	1.38	2.08	1.22	
22:5w6	1.65	1.14	1.61	1.60	1.18	2.22	1.60	1.87	2.20	1.82	
22:5w3	3.09	3.16	2.04	2.15	2.72	2.38	2.57	2.44	1.88	2.17	
22:6w3	25.21	27.03	26.61	23.58	23.28	28.78	25.13	27.68	28.82	25.50	
Fatty acid (% of total lipid)	-	67.6	-	69.6	-	67.8	-	-	-	-	
Sterols (%)	-	9.7	-	9.3	-	12.9	-	-	-	-	

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Table 17. *Proximate, lipid, and fatty-acid composition of filets from samples of pike, walleye* (Stizostedion vitreum)

Fish no.	*F47*	*F52*	*F61*	*F64*	*F65*	*F66*	*F67*	Avg.
Weight (g)	435	473	403	609	508	423	356	
Length (mm)	370	375	335	360	350	337	330	
Filet weight (g)	158	139	121	215	158	115	95	
Moisture (%)	79.0	79.7	78.4	77.7	78.5	78.8	78.0	78.6
Lipid (%)	1.0	0.6	1.4	1.3	1.1	1.1	1.1	1.1
Protein (%)	19.1	-	19.8	19.5	-	-	-	19.5
Ash (%)	1.3	-	1.2	1.2	-	-	-	1.2
								100.4%
Fatty acid (%)								
14:0	1.9	1.5	1.8	1.9	1.7	1.6	1.4	
16:0	20.0	20.0	18.1	18.9	19.8	17.5	18.2	
16:1	9.6	5.9	10.8	10.7	10.1	9.7	9.3	
18:0	2.6	3.9	3.2	3.2	3.4	3.3	3.7	
18:1	19.7	12.5	21.6	20.7	18.9	19.5	18.5	
18:2*w*6	1.9	1.5	2.6	2.3	1.9	2.6	2.1	
18:3*w*3	1.8	1.4	1.9	1.8	1.6	1.7	1.6	
18:4*w*3	0.7	0.4	0.7	0.8	0.6	0.6	0.6	
20:0	-	0.2	0.1	0.1	-	0.1	-	
20:1	0.5	0.4	0.4	0.4	0.3	0.4	0.4	
20:2	-	-	0.1	0.1	-	0.1	-	
20:3	-	-	0.2	0.2	0.4	0.1	0.1	
20:4*w*6	6.1	8.6	5.6	5.8	6.4	6.1	6.3	
20:4*w*3	-	-	0.2	0.3	0.4	0.2	0.3	
20:5*w*3	8.5	9.5	7.0	7.6	8.7	8.1	7.7	
22:4*w*6	0.7	0.8	0.8	0.7	0.7	0.8	0.8	
22:5*w*6	1.8	2.3	1.6	1.4	1.7	1.7	1.9	
22:5*w*3	2.2	2.1	1.8	1.5	1.2	1.9	1.9	
22:6*w*3	20.2	26.8	18.9	19.3	21.2	21.7	23.0	
17:1	0.6	0.6	1.0	0.8	0.4	0.8	0.8	
22:1	0.7	-	0.1	0.2	0.1	0.1	0.2	
Fatty acid (% of total lipid)	72.2	-	-	70.2	-	-	-	
Sterols (%)	5.7	-	4.8	9.0	-	-	-	

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Table 18. *Proximate, lipid, and fatty-acid composition of filets from samples of smelt, American* (Osmerus mordax)

Fish no.	*F127*	*F128*	*F129*	*F130*	*F131*	*F132*	Avg.
Weight (g)*	43.9	36.2	77.3	40.9	35.4	37.3	
Length (mm)	183	179	208	185	162	181	
Filet weight (g)	13.6	15.9	25.0	16.6	12.7	15.7	
Moisture (%)	78.7	76.9	-	-	-	-	77.8
Lipid (%)	1.8	1.9	1.9	2.4	2.1	2.8	2.2
Protein (%)	18.0	18.5	-	-	-	-	18.3
Ash (%)	1.2	1.1	-	-	-	-	1.2
							99.4%
Fatty acid (%)							
14:0	4.30	4.45	4.57	4.53	4.54	4.94	
16:0	13.89	14.10	13.93	13.79	13.85	13.22	
16:1	8.67	8.61	8.94	9.03	9.07	9.72	
18:0	1.37	1.21	1.50	1.31	1.29	1.19	
18:1	16.23	16.69	18.08	17.37	16.95	19.52	
18:2w6	3.76	3.22	3.83	3.94	3.38	3.70	
18:3w3	4.25	4.26	4.73	4.56	4.31	4.75	
18:4w3	1.38	1.66	1.49	1.85	1.68	1.85	
20:0	0.15	0.17	0.23	0.16	0.16	0.16	
20:1	-	-	-	-	-	-	
20:2	0.13	0.15	0.13	0.14	0.09	0.09	
20:3	-	-	-	-	-	-	
20:4w6	3.77	3.35	3.83	3.25	3.78	3.24	
20:4w3	0.22	0.30	0.38	0.50	0.26	0.39	
20:5w3	13.82	14.11	11.63	12.70	14.02	13.77	
22:4w6	0.21	0.21	0.20	0.27	0.31	0.37	
22:5w6	1.10	1.02	1.29	1.17	1.06	0.95	
22:5w3	0.82	0.92	0.98	1.07	0.74	0.88	
22:6w3	24.23	23.85	22.41	22.49	22.77	19.17	
Fatty acid (% of total lipid)	68.4	74.4	-	-	-	-	
Sterols (%)	4.5	3.8	-	-	-	-	

* *All data represent the average for three fish.*

Table 19. *Proximate, lipid, and fatty-acid composition of filets from samples of sucker, white* (Catostomus commersonni)

Fish no.	*F38*	*F43*	*F36*	*F49*	*F50*	Avg.
Weight (g)	1231	762	1596	834	1392	
Length (mm)	450	437	492	410	450	
Filet weight (g)	306	217	327	284	456	
Moisture (%)	76.5	80.7	77.6	79.5	78.6	78.6
Lipid (%)	2.3	1.8	1.8	1.8	1.8	1.9
Protein (%)	-	16.2	-	18.4	16.2	16.9
Ash (%)	-	1.1	-	1.1	1.3	1.2
Fatty acid (%)						98.6%
14:0	2.2	3.4	2.9	2.0	1.9	
16:0	13.9	15.4	14.8	15.8	16.5	
16:1	21.3	15.5	20.8	18.7	17.8	
18:0	1.4	2.3	2.0	2.6	2.8	
18:1	12.5	17.2	12.4	15.9	13.7	
18:2w6	3.0	3.8	2.2	2.3	2.4	
18:3w3	1.6	3.2	2.1	2.2	2.5	
18:4w3	1.8	1.4	2.3	1.8	2.0	
20:0	0.7	0.5	0.5	0.5	0.4	
20:1	0.6	1.4	1.3	1.3	1.4	
20:2	-	0.6	0.2	0.3	0.5	
20:3	-	0.3	0.3	0.3	0.4	
20:4w6	2.5	4.0	4.0	4.7	6.3	
20:4w3	0.4	0.4	0.4	0.7	0.5	
20:5w3	14.3	6.8	11.4	9.9	9.2	
22:4w6	-	0.5	0.3	1.0	0.9	
22:5w6	-	1.2	0.6	0.9	1.1	
22:5w3	3.1	3.4	3.4	3.9	3.2	
22:6w3	16.5	14.9	15.6	13.2	14.1	
17:1	2.4	0.8	1.4	1.0	1.1	
22:1	0.7	1.5	0.5	0.3	0.4	
Fatty acid (% of total lipid)	-	82.2	-	81.1	81.0	
Sterols (%)	-	2.7	-	3.5	3.7	

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Table 20. *Proximate, lipid, and fatty-acid composition of filets from samples of sunfish, pumpkinseed* (Lepomis gibbosus)

Fish no.	*F62*	*F63*	*F68*	*F69*	*F70*	*F98*	*F99*	*F100*	Avg.
Weight (g)	170	290	227	195	272	208	269	225	
Length (mm)	185	207	205	192	240	212	201	212	
Filet weight (g)	35	69	61	46	59	39	58	38.5	
Moisture (%)	79.3	79.3	69.4	79.0	79.1	79.3	79.4	80.8	79.5
Lipid (%)	0.7	1.1	0.6	0.7	0.7	0.6	0.4	0.5	.7
Protein (%)	-	-	18.9	19.6	19.6	-	-	-	19.4
Ash (%)	-	-	1.1	1.0	1.1	-	-	-	1.1
Fatty acid (%)									100.7%
14:0	1.5	3.1	3.4	2.3	2.9	1.56	1.93	1.71	
16:0	17.9	17.0	21.1	19.7	19.4	18.30	18.80	17.85	
16:1	5.1	12.9	9.1	7.9	9.5	5.97	6.30	6.57	
18:0	5.8	4.2	4.7	6.3	5.3	5.19	5.55	5.05	
18:1	11.5	18.3	14.4	12.7	16.8	9.55	11.64	10.99	
18:2ω6	2.5	3.2	2.6	2.2	3.8	2.48	2.94	3.59	
18:3ω3	1.5	2.8	1.9	1.5	2.7	0.48	1.63	2.47	
18:4ω3	0.3	0.5	-	-	-	0.36	0.36	0.32	
20:0	0.3	0.2	-	-	-	-	-	-	
20:1	0.9	1.4	1.0	0.9	0.9	-	-	-	
20:2	0.7	0.5	0.9	0.5	0.3	0.56	0.54	0.56	
20:3	0.3	0.3	0.5	0.2	0.3	0.62	0.44	0.72	
20:4ω6	16.3	9.2	16.0	15.8	11.9	17.84	16.00	16.33	
20:4ω3	0.5	0.6	-	-	0.2	0.39	0.29	0.38	
20:5ω3	7.1	5.0	5.1	7.7	5.9	9.42	7.91	8.33	
22:4ω6	1.6	1.2	1.5	1.3	0.9	1.58	1.47	1.47	
22:5ω6	3.7	2.5	3.7	2.8	2.5	3.01	3.13	2.69	
22:5ω3	3.5	3.7	2.6	3.8	2.8	3.64	2.81	3.19	
22:6ω3	17.2	11.8	10.0	12.8	11.8	16.14	15.57	14.28	
Fatty acid (% of total lipid)	65.8	-	-	-	-	-	68.1	71.8	
Sterols (%)	-	-	-	-	-	12.1	11.6	12.0	

Table 21. *Proximate, lipid, and fatty-acid composition of filets from samples of trout, brook* (Salvelinus fontinalis)

Fish no.	*101*	*102*	*103*	*104*	*105*	*106*	*107*	*108*	Avg.
Weight (g) (eviscerated)	119	88	172	182	121	95	69	79	
Length (mm)	217	205	245	275	222	205	193	190	
Filet weight (g)	70.2	42.5	105	101	75	54	37.8	33	
Moisture (%)	72.16	76.7	72.6	75.73	73.2	73.8	74.1	76.4	74.3
Lipid (%)	5.2	2.6	4.2	2.0	4.0	4.1	2.9	2.1	3.4
Protein (%)	-	-	21.7	-	20.9	21.8	-	-	21.5
Ash (%)	-	-	1.4	-	1.3	1.3	-	-	1.3
Fatty acid (%)									100.4%
14:0	3.61	3.80	4.08	3.54	3.52	3.43	3.56	4.05	
16:0	17.19	16.31	18.14	20.39	17.97	18.04	17.63	17.64	
16:1	13.89	9.69	13.45	8.64	11.90	13.89	10.33	7.92	
18:0	3.87	3.81	3.48	4.61	4.40	3.83	4.27	3.95	
18:1	24.79	19.28	22.08	18.10	24.58	24.63	21.10	15.30	
18:2ω6	5.42	5.68	5.40	6.17	5.11	4.94	4.82	6.34	
18:3ω3	6.12	6.85	5.87	5.19	5.62	5.46	6.18	6.52	
18:4ω3	2.53	3.66	2.88	1.98	2.37	2.66	2.86	3.58	
20:0	0.29	0.28	0.47	0.29	0.18	0.22	0.13	-	
20:3	0.23	0.17	0.39	0.21	0.15	0.34	0.16	0.34	
20:4ω6	4.00	4.35	3.90	4.83	4.26	3.93	4.51	4.68	
20:4ω3	0.97	1.40	1.03	0.42	0.98	1.06	1.12	1.41	
20:5ω3	6.21	8.12	6.38	7.40	6.60	5.95	7.78	8.16	
22:4ω6	0.25	0.20	0.22	-	0.18	0.23	0.14	0.42	
22:5ω6	0.30	0.35	0.48	0.34	0.53	0.51	0.65	0.77	
22:5ω3	1.24	1.65	1.58	1.87	1.54	1.47	1.77	1.68	
22:6ω3	6.57	10.88	7.38	13.95	7.04	7.22	9.45	12.22	
Fatty acid (% of total lipid)	-	-	81.0	-	81.4	75.8	-	-	
Sterols (%)	-	-	2.0	-	1.8	2.0	-	-	

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Table 22. *Proximate, lipid, and fatty-acid composition of filets from samples of trout, lake* (Salvelinus namaycush)

Fish no.	*F57*	*F58*	*F59*	*F60*	Avg.
Weight (g)	1617	2863	2281	2845	
Length (mm)	555	700	620	660	
Filet weight (g)	595	1181	795	1153	
Moisture (%)	73.4	71.5	75.6	69.0	72.4
Lipid (%)	6.4	10.9	5.1	6.2	7.2
Protein (%)	18.5	-	19.1	18.3	18.6
Ash (%)	1.2	-	1.1	1.1	1.1
Fatty acid (%)					99.3%
14:0	3.6	3.5	3.3	3.3	
16:0	13.8	12.4	14.4	13.1	
16:1	8.4	9.0	9.1	12.0	
18:0	3.1	2.6	2.9	2.1	
18:1	26.3	28.8	28.9	31.8	
18:2*w*6	3.7	4.2	3.4	3.1	
18:3*w*3	3.1	3.4	2.6	2.6	
18:4*w*3	1.3	1.3	0.8	0.8	
20:0	0.4	0.4	0.3	0.2	
20:1	2.0	2.2	2.3	1.7	
20:2	0.4	0.5	0.5	0.4	
20:3	0.4	0.4	0.4	0.3	
20:4*w*6	3.8	3.8	4.4	3.2	
20:4*w*3	1.7	1.7	1.4	1.1	
20:5*w*3	4.8	4.5	4.5	6.0	
22:4*w*6	0.9	0.9	0.9	0.5	
22:5*w*6	1.8	2.0	1.9	1.4	
22:5*w*3	2.7	3.2	2.9	2.9	
22:6*w*3	15.1	12.9	13.4	12.4	
22:1	0.6	0.7	0.6	0.4	
Fatty acid (% of total lipid)	79.8	-	75.2	80.8	
Sterols (%)	0.8	-	0.9	0.9	

Table 23. *Proximate, lipid, and fatty-acid composition of filets from samples of trout, rainbow* (Salmo gairdneri)

Fish no.	*133*	*134*	*135*	*136*	*137*	*138*	Avg.
Weight (g)	798	703	435	542	303	312	
Length (mm)	432	410	305	365	320	320	
Filet weight (g)	324	334	189	216	130	148	
Moisture (%)	76.4	75.5	78.2	-	78.1	76.3	76.9
Lipid (%)	5.4	3.5	2.7	2.8	1.7	2.6	3.1
Protein (%)	18.6	19.4	18.5	-	-	-	18.8
Ash (%)	-	-	-	1.3	1.3	1.3	1.3
Fatty acid (%)							100.2%
14:0	3.96	3.77	2.98	3.49	2.93	3.68	
16:0	13.06	14.28	13.38	12.83	13.03	13.37	
16:1	5.70	5.57	4.51	4.94	3.29	4.58	
18:0	4.10	3.80	4.36	3.30	3.70	3.56	
18:1	22.10	19.69	18.65	20.24	14.28	17.15	
18:2*w*6	6.10	5.35	5.56	5.70	4.98	5.13	
18:3*w*3	6.70	5.98	5.64	6.33	5.20	5.77	
18:4*w*3	2.55	2.03	1.61	2.22	1.70	2.35	
20:0	0.29	0.17	-	0.08	0.10	-	
20:1	-	-	-	-	-	-	
20:2	-	-	-	-	-	-	
20:3	0.63	-	0.29	0.15	0.19	0.22	
20:4*w*6	4.52	4.02	4.38	4.20	4.82	4.55	
20:4*w*3	3.38	2.79	2.58	2.48	2.72	2.70	
20:5*w*3	4.85	4.93	4.04	5.75	5.21	5.62	
22:4*w*6	1.27	.91	1.29	0.59	0.93	0.64	
22:5*w*6	2.11	2.06	2.85	2.02	3.30	2.69	
22:5*w*3	3.69	3.64	3.78	3.39	4.08	3.56	
22:6*w*3	12.76	18.31	22.65	20.98	28.53	23.03	
Fatty acid (% of total lipid)	-	-	-	71.6	75.4	70.0	
Sterols (%)	-	-	-	1.7	2.8	2.3	

Table 24. *Proximate, lipid, and fatty-acid composition of filets from samples of carp* (Cyprinus carpio)

Fish no.	*F48*	*F56*
Weight (g)	177	1998
Length (mm)	210	465
Filet weight (g)	56	595
Moisture (%)	80.6	76.2
Lipid (%)	1.0	2.6
Fatty acid (%)		
14:0	1.5	2.3
16:0	17.6	18.0
16:1	9.8	14.7
18:0	3.8	3.4
18:1	14.3	26.4
18:2*w*6	4.9	5.0
18:3*w*3	2.7	5.5
18:4*w*3	-	0.9
20:0	-	0.4
20:1	1.6	3.2
20:2	0.6	0.6
20:3	0.6	0.5
20:4*w*6	7.9	4.5
20:4*w*3	0.9	0.7
20:5*w*3	10.4	5.0
22:4*w*6	0.9	1.0
22:5*w*6	0.9	0.7
22:5*w*3	4.7	1.3
22:6*w*3	13.5	2.7

Table 25. *Proximate, lipid, and fatty-acid composition of filets from samples of pike, northern* (Esox Lucius)

Fish no.	*F51*
Weight (g)	978
Length (mm)	550
Filet weight (g)	321
Moisture (%)	79.8
Lipid (%)	0.7
Fatty acid (%)	
14:0	1.1
15:1	1.6
16:0	15.7
16:1	2.9
18:0	3.7
18:1	6.8
18:2*w*6	2.5
18:3*w*3	2.7
18:4*w*3	0.8
20:0	-
20:1	0.3
20:2	-
20:3	-
20:4*w*6	8.0
20:4*w*3	-
20:5*w*3	10.0
20:4*w*6	-
22:5*w*6	2.0
22:5*w*3	2.5
22:6*w*3	39.4

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