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LIPIDS IN FISH FILLET AND LIVER – A COMPARISON OF FATTY ACID COMPOSITIONS

by

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INTRODUCTION

Much new information on fatty acid composition in fish lipids has been published since the introduction of gas chromatography as a method of analysis. A comprehensive review of older results, mainly based on fractional distillation of fatty acid esters, is found in the monograph by HILDITCH and WILLIAMS (1964). Results from gas chromatographic analyses reported in the literature are usually based on scattered tissue samples of fishes and of fish oils from many parts of the world.

Two major types of fish oils have commercial value. Fish liver oils have been produced from livers of many species, mainly because of their vitamin contents. Presently, cod liver oil is the main liver oil of any importance in this group. Fatty acid composition of cod liver oils has been reported from several laboratories, and a review was published by LAMBERTSEN and BRÆKKAN (1965a). Seasonal variations were reported by JANGAARD, ACKMAN and SIPOS (1967). The most important fish oils are of body oils of different species of pelagic fishes, particularly of clupeids. LAMBERTSEN and BRÆKKAN (1965b) have published a review of fatty acid analyses of different herring oils, ACKMAN and EATON (1966) reported fatty acid compositions of some commercial Atlantic herring oils. The fatty acid compostions of some Norwegian fish oils of different origin were reported by URDAL and NYGÅRD (1971).

Fish liver oils are produced from species which have their major fat depot in the livers, and less than 1% triglyceride fat in muscle tissue. The liver may contain 30—70% of fat. Body oils are mainly produced from species having their major fat depot in muscle tissues with percentages in the order of 5—30%. Such species may have secondary mesenteric fat depots, but the livers are generally low in fat.

All industrial fish oils have fatty acid compositions characterizing them generally as marine lipids, in that the highly unsaturated acids 18:4ω3,[1]) 20:5ω3 and 22:6ω3, and monoenoic acids as 16:1ω9, 20:1ω11, and 22:1ω11 range as major components. But typical differences are also seen, such as much higher percentages of 14:0 and 16:1ω9 in herring oils

[1]) Fatty acid code: 18: Chain length, 18 carbon atoms, :4: four methylene-interrupted double bonds, ω3: last double bond is 3 carbons removed from methyl end group.

than in cod liver oils, and a 16:0 to 16:1 ratio of about 2 in herring oils compared to 1.2 in cod liver oils.

The present work gives fatty acid compositions in liver and fillet of four different species of fish which all have fat depots in the liver as well as in the fillet (muscle).

METHODS

Samples.

Tissues for analysis were taken from four completely fresh fishes of each species. Catfish, plaice and wrasse were bought round in the Bergen fish market whereas the redfish samples were cleaned and frozen with packed livers inside in a northern Norwegian frozen fish plant. Whole livers were used, and skin- and boneless fillet samples were taken from the back of the fish. Socalled dark muscle was avoided.

Lipid extraction.

The samples were frozen, ground in a meat grinder while still at temperatures around 0°C, and dropped into methanol. The suspension was given a quick boil-up to ensure protein denaturation and water extraction, cooled and centrifuged. The residue was extracted several times with chloroform, and the methanol extract was partly evaporated and possible lipids extracted by ethyl ether, and this was added to the main chloroform extract. The lipid solutions were dried over sodium sulphate and the solvent evaporated in vacuum. The lipid samples were kept in closed vials at —20°C.

Separation of "polar" from "non-polar" lipids.

The lipid extracts were fractioned on columns of alumina. "Non-polar" lipids, consisting of hydrocarbons, triglycerides, sterylesters etc., were eluted with a mixture of hexane-ethyl ether (4:1). The appearance of free sterols in the eluate (Liebermann-Buchard reaction) indicated the end of the non-polar fraction, and the elution was continued with methanol-chloroform (1:3). The "polar" fraction contained mainly the phospholipids, whereas more acid products, free fatty acids and some products of oxidation remained on the column. The solvent was removed in vacuum.

Preparation of fatty acid methyl esters.

Samples of lipid fractions weighing not more than 1 g were saponified by boiling for 20 min. in 50 ml methanol with 3 ml 60% KOH (w/v), and with pyrogallol and ascorbid acid added to avoid oxidation. After addi-

tion of water, the unsaponifiable matter was extracted with ethyl ether, which was reextracted with water containing a few drops 1 N NaOH-solution. The combined soap solution was acidified with 1 n hydrochloric acid and extracted three times with ethyl ether. This fatty acid extract was washed with water, evaporated in vacuum and dissolved in methanol containing 10% BF_3 and methylated by boiling for 5 min. After addition of water, the methyl esters were extracted in ethyl ether, washed and evaporated in vacuum. The esters were taken up in a few ml of hexane and impurities (oxidation products etc.) removed by chromatography on short columns of alumina, using 5% ethyl ether in hexane as eluent. After evaporation, the metyl esters were dissolved in methyl hexanoate to a concentration of 5%, and stored in well-closed vials at −20°C.

Hydrogenation.

An aliquot of the esters was hydrogenated by shaking the methyl hexanoate solution under hydrogen gas at a pressure of 2 atm. at room temperature with a few grains of palladium on char-coal added as a catalyst. 4 h sufficed for complete hydrogenation. The catalyst was removed by filtration.

Gas chromatography.

Instrument: Pye-Argon Chromatograph, based on constant temperature of 190°C, argon carrier gas at 40−50° ml/min and a Sr ^{90}-ionization detector. The instrument was modified with an extra heated injection port.

Columns: Straight, 5′ · 1/4″ glass columns filled with silanized celite 80−100 mesh (lab-purified from kieselguhr Merck).

Stationary phase: 10% SE-30 silicon polymer for hydrogenated samples, 20% butanediol-succinate polyester (BDS) for non-hydrogenated samples.

Calculation was based on peak-height times width at half height. Partly overlapping peaks were sorted out by hand drawing.

Peak areas were calculated from three runs of each sample and averaged. SE-30-charts from fully hydrogenated samples were used to calculate chain-length composition. The sum was converted to 99%, giving 1% as non-calculated peaks. The peaks were identified by their retention time relative to 18:0 standard and checked by a "semi-log plot". Further identification of branched chain acids was not attempted.

Unsaturated acids were calculated from BDS-charts for each chain-length. The sum of acids of the same chainlength was converted to the percentage of this chainlength found from analysis of the corresponding hydrogenated sample.

RESULTS AND DISCUSSION

Table 1. Lipid contents in tissues and methyl ester recoveries.

Species (Engl.—Norw. systematic)	Lipids in (g/100 g extracted tissue) fillet	*liver*	% Methyl esters from fillet non-polar/pol.		*liver* *non-polar/pol.*	
Catfish / steinbit Anarichas lupus	3 (82—18)[1]	*11* *(90—10)*	84	40	*59*	*20*
Plaice / rødspette Pleuronectes platessa	1.5 (89—11)	*19* *(92—8)*	57	30	*79*	*31*
Redfish / uer Sebastes marinus	4 (97—3)	*28* *(98—2)*	93	51	*92*	*16*
Wrasse / berggylt Labrus berggylta	2 (89—11)	*10* *(73—27)*	87	54	*84*	*29*

[1]) non-polar — polar percentages

Table 1 gives some information on the lipid fractions which were analysed for fatty acid composition. The fish fillet samples were somewhat low in fat, from 1.5 to 4%, whereas the livers gave values from 10 to 28%. The four species investigated all belong to the group of medium fat fishes, which may have filets showing up to 10% fat, varying with the time of the year. Six of the eight lipid extracts gave 89 to 98% "non-polar" (triglyceride) lipids, and correspondingly 2 to 11% of "polar" (phospho-)lipids. Catfish filet gave 18%, and wrasse liver 27% phospholipids.

The methylation of these fractions gave 79 to 93% methyl esters from the non-polar fractions, and 29 to 54% from the polar fractions. In all, 16 fractions of methyl esters were prepared from the four fish species.

The results from the gas-chromatographic determination of the fatty acid compositions of the 16 fractions are compiled in tables 2 and 3. As there are several variables in this study, the results will be discussed under separate headings.

Analytical considerations.

Gas chromatography of fatty acid methyl esters as a quantitative method for the determination of fatty acid composition rests mainly on the relation between "peak area" and weight percentage of component, and on means of identification of the peaks. Early work with standard fatty acids has shown that generally there is good correlation between weight percentages and peak area, the latter calculated as a rectangle

with height equal to peak height and width equal to peak width at half height. This calculation is complicated by base line variations, by subsequent elution of minor and major peaks often partly overlapping, and with weight percentages differing as much as 1:100. A particular complication lies in the normal mixture of different homologous series of fatty acids with from nil to six double bonds at varying positions. Even if these series all give corresponding ratios between peak areas and weight percentages — which is not absolutely proven — they react differently in the GLC process, and may therefore escape from the column at different peak widths. Fish oils have particularly complicated fatty acid compositions, and should be calculated carefully. The problems discussed above are best overcome by complete hydrogenation of an aliquot of the fatty acid methyl esters. This reduces the mixture to one homologous series of saturated straight chain acids together with, in most cases, only minor amounts of branched chain acids. These are eluted according to their vapour pressure differences on a non-polar column, e.g. of the silicon polymer SE 30 as in the present work, and give well separated peaks, easy to calculate and with accurate ratios of peak area to weight percentage. Furthermore, non-polar GLC columns have generally higher theoretical plate values and better thermal stability than columns of polar phases, e.g. of polyesters.

When a calculation of the fatty acid composition by chain length is achieved, the different unsaturated acids must be estimated by GLC on a polar stationary phase. Partly or wholly overlapping peaks is the rule more than the exception in work or fish lipids. Very narrow peak widths, by which overlapping can be partly avoided, are obtained by GLC with capillary columns as Ackman and his group has shown in several excellent analyses with columns of 0.01″ × 150″ (e.g. Ackman and Castell (1967).

Using ordinary columns, 4′ to 7′, some resolution of overlapping peaks can be obtained by running the samples through two columns of different polar stationary phases.

The presence of more than one fatty acid isomer within one chain length and unsaturation, e.g. 20:4 ω3 and 20:4 ω6, makes complete separations practically impossible with normal columns. We have separated the fatty acid methyl esters into groups of "critical partners" (as 16:0 + 18:1 + 20:2 + 22:3) by partition thin layer chromatography using paraffin as the stationary phase and acetonitrile/isopropanol as the mobile phase (Lambertsen, Myklestad and Brækkan (1966)). Such fractions give much better separable and identifiable peaks on subsequent GLC, but the method is time-consuming, and has been used only when a complete analysis was felt necessary.

Table 2. Fatty acid compositions of fish lipids — non-polar (triglyceride) fractions.

Fatty acid designation	Cat-fish		Plaice		Red-fish		Wrasse		Average values	
	filet	*liver*	filet	*liver*	filet	*liver*	filet	*liver*	filet	*liver*
14:0	3.2	*1.5*	3.5	*4.1*	6.4	*2.3*	3.8	*5.9*	4.2	*3.5*
16:0	10.3	*10.8*	16.9	*19.9*	14.3	*12.7*	11.9	*11.2*	13.4	*13.7*
18:0	2.0	*3.3*	3.4	*1.5*	1.8	*3.2*	5.8	*4.0*	3.3	*3.0*
Saturated	**15.5**	**15.6**	**23.8**	**25.5**	**22.5**	**18.2**	**21.5**	**21.1**	**20.9**	**20.2**
16:1	9.2	*8.9*	13.3	*17.8*	7.0	*9.4*	7.9	*9.7*	9.4	*11.5*
18:1	24.1	*28.6*	19.6	*29.8*	21.5	*40.2*	20.5	*22.8*	21.4	*30.4*
20:1	5.6	*2.3*	5.6	*5.1*	10.8	*6.5*	4.9	*5.2*	6.7	*4.8*
22:1	0.9	*0.2*	2.7	*0.6*	9.3	*2.5*	0.8	*0.5*	3.4	*0.9*
Monoenes	**39.8**	**40.0**	**41.2**	**53.3**	**48.6**	**58.6**	**34.1**	**38.2**	**40.9**	**47.5**
18:4	3.1	*1.0*	1.5	*0.3*	2.9	*0.2*	2.2	*2.4*	2.4	*1.0*
20:5	12.7	*13.7*	9.5	*5.2*	10.2	*8.1*	12.1	*12.4*	11.1	*9.8*
22:6	12.3	*9.8*	7.7	*4.1*	6.6	*5.1*	14.4	*7.6*	10.3	*6.7*
Fully unsat. polyenes	**28.1**	**24.5**	**18.7**	**9.6**	**19.7**	**13.4**	**28.7**	**22.4**	**23.8**	**17.5**

16:2	0.2	—	0.6	*0.2*	0.2	*0.5*	0.4	—	0.4	*0.2*
16:3	0.3	*0.2*	0.3	*0.2*	0.2	*0.2*	0.5	*0.5*	0.3	*0.3*
18:2	1.1	*0.8*	1.1	*0.6*	1.2	*1.0*	0.7	*1.2*	1.0	*0.9*
18:3	0.5	*0.3*	0.7	*0.3*	0.8	*0.5*	0.4	*0.7*	0.6	*0.5*
20:2	0.8	*1.0*	0.6	*0.5*	0.2	*0.1*	0.3	*0.9*	0.5	*0.6*
20:3+4	4.6	*8.2*	2.8	*1.8*	0.5	*0.4*	4.2	*4.8*	3.0	*3.8*
22:2	0.1	*0.2*	0.5	*0.6*	0.4	*0.3*	0.1	—	0.3	*0.3*
22:3+4	0.6	*1.0*	1.5	*1.2*	0.8	*1.4*	0.8	*1.1*	0.9	*1.2*
22:5	2.2	*1.3*	2.8	*1.3*	1.0	*1,6*	2.8	*1.2*	2.2	*1.3*
Medium polyenes	**10.4**	**13.0**	**10.9**	**6.7**	**5.3**	**6.0**	**10.2**	**10.4**	**9.2**	**9.1**
15:—	0.5	*0.3*	0.6	*0.4*	0.5	*0.2*	0.5	*0.7*	0.5	*0.4*
17:—	1.0	*1.3*	0.8	*0.9*	0.7	*0.6*	1.1	*1.2*	0.9	*1.0*
19:—	0.7	*0.7*	0.4	*0.4*	0.4	*0.3*	0.6	*0.5*	0.5	*0.5*
21:—	0.7	*0.4*	0.5	*0.5*	0.4	*0.7*	0.5	*0.4*	0.5	*0.5*
Odd-no acids	**2.9**	**2.7**	**2.3**	**2.2**	**2.0**	**1.8**	**2.7**	**2.8**	**2.5**	**2.4**
15:br	0.4	*0.1*	0.6	*0.3*	0.4	*0.2*	0.4	*1.1*	0.5	*0.4*
17:brI	0.8	*1.7*	0.4	*0,3*	0.1	—	0.4	*0.5*	0.4	*0.6*
17:brII	0.7	*1.1*	0.7	*0.7*	0.2	*0.4*	0.6	*1.0*	0.6	*0.8*
16:br	0.2	*0.2*	0.4	*0.3*	—	—	0.1	*0.3*	0.2	*0.2*
18:br	0.2	*0.3*	—	—	0.2	*0.3*	0.3	*0.2*	0.2	*0.2*
Branched acids	**2.3**	**3.4**	**2.1**	**1.6**	**0.9**	**0.9**	**1.8**	**3.1**	**1.8**	**2.2**
Non-calc	**1.0**	**0.8**	**1.1**	**1.1**	**1.0**	**1.1**	**1.0**	**1.0**	**1.0**	**1.1**

Table 3. Fatty acid compositions of fish lipids — polar (phospholipid) fractions.

Fatty acid designation	Cat-fish		Plaice		Red-fish		Wrasse		Average values	
	filet	*liver*	filet	*liver*	filet	*liver*	filet	*liver*	filet	*liver*
14:0	0.8	*1.0*	1,7	*1.7*	2.6	*2.9*	0.7	*2.4*	1.4	*2.0*
16:0	15.8	*10.9*	25.8	*26.7*	24.9	*19.3*	15.4	*18.8*	20.5	*18.9*
18:0	2.2	*3.1*	1.7	*2.0*	2.5	*3.3*	2.8	*2.7*	2.3	*2.8*
Saturated	**18.8**	**15.0**	**29.2**	**30.4**	**30.0**	**25.5**	**18.9**	**23.9**	**24.2**	**23.7**
16:1	3.0	*6.4*	4.8	*5.7*	3.2	*4.9*	2.1	*5.3*	3.3	*5.6*
18:1	14.0	*22.1*	11.4	*13.3*	11.9	*18.0*	12.4	*12.9*	12.4	*16.6*
20:1	1.3	*2.1*	1.0	*1.2*	2.7	*3.0*	1.0	*1.4*	1.5	*1.9*
22:1	0.2	*0.1*	0.3	*0.4*	1.3	*1.3*	—	*0.2*	0.4	*0.5*
Monoenes	**18.5**	**30.7**	**17.5**	**20.6**	**19.1**	**27.2**	**15.5**	**19.8**	**17.6**	**24.6**
18:4	0.4	*0.6*	0.1	*0.3*	1.3	*0.7*	0.4	*1.2*	0.5	*0.7*
20:5	18.5	*16.8*	23.0	*10.4*	13.8	*16.3*	14.6	*18.6*	17.5	*15.5*
22:6	23.7	*14.5*	9.9	*23.6*	25.6	*19.1*	33.0	*20.0*	23.1	*19.3*
Fully unsat. polyenes	**42.6**	**31.9**	**33.0**	**34.3**	**40.7**	**36.1**	**48.0**	**39.8**	**41.1**	**35.5**

16:2	0.2	—	0.2	*0.2*	0.2	*0.4*	—	*0.3*	0.2	*0.2*
16:3	0.5	*0.4*	0.1	*0.3*	0.2	*0.2*	—	*0.3*	0.2	*0.3*
18:2	0.8	*0.7*	1.0	*0.3*	1.6	*1.1*	0.5	*0.8*	1.0	*0.7*
18:3	0.2	*0.4*	0.3	*0.2*	0.8	*0.4*	0.2	*0.4*	0.4	*0.4*
20:2	0.5	*0.8*	0.2	*0.2*	0.2	*0.2*	0.3	*0.3*	0.3	*0.4*
20:3+4	10.0	*11.0*	7.2	*4.8*	2.2	*1.2*	6.5	*6.0*	6.4	*5.7*
22:2	0.1	*0,2*	—	—	—	*0.2*	—	*0.1*	—	*0.1*
22:3+4	0.9	*1.3*	2.3	*1.2*	0.9	*1.9*	1.3	*1.0*	1.4	*1.4*
22:5	1.8	*1.5*	3.4	*3.3*	1.3	*2.2*	4.5	*2.3*	2.7	*2.3*
Medium polyenes	**15.0**	**16.3**	**14.7**	**10.5**	**7.4**	**7.8**	**13.3**	**11.5**	**12.6**	**11.5**
15:—	0.6	*0.3*	1.9	*0.6*	0.4	*0.4*	0.3	*0.6*	0.8	*0.5*
17:—	1.6	*1.1*	1.3	*0.9*	0.6	*0.7*	1.2	*0.9*	1.2	*0.9*
19:—	0.3	*0.4*	0.3	*0.3*	0.5	*0.4*	0.3	*0.3*	0.3	*0.4*
21:—	0.4	*0.3*	0.5	—	—	—	0.3	*0.3*	0.3	*0.1*
Odd-no acids	**2.9**	**2.1**	**4.0**	**1.8**	**1.5**	**1.5**	**2.1**	**2.1**	**2.6**	**1.9**
15:br	—	*0.1*	0.1	*0.2*	0.2	*0.2*	—	*0.4*	0.1	*0.2*
17:brI	0.4	*2.0*	0.2	*0.6*	—	*0.5*	0.4	*0.4*	0.2	*0.9*
17:brII	0.5	*0.5*	0.2	*0.5*	0.2	*0.2*	0.4	*0.8*	0.3	*0.5*
16:br	0.1	*0.1*	0.1	*0.2*	—	*0.1*	0.1	*0.2*	0.1	*0.2*
18:br	0.2	*0.3*	—	—	—	—	0.2	*0.3*	0.1	*0.1*
Branched acids	**1.2**	**3.0**	**0.6**	**1.5**	**0.4**	**1.0**	**1.1**	**2.1**	**0.8**	**1.9**
Non-calc	**1.0**	**1.0**	**1.0**	**0.9**	**1.0**	**0.9**	**0.9**	**0.8**	**1.1**	**0.9**

Only one type of polar column (20% BDS-polyester on celite, 5′ · ¼″ column) was used in the present analyses. Overlapping major peaks as 18:4 / 20:1 and 20:5 / 22:1 were calculated by difference correction from the chain length value obtained from the hydrogenated sample runs on non-polar GLC, assuming linearity between peak area and weight percentage for both types of GLC. Minor unsaturated fatty acids as 20:3 and 20:4 were given as sum values, and no attempt was done to separate unsaturated isomers. Odd-numbered acids and branched chain acids were calculated only from the hydrogenated samples. Some minor acids could not be seen in this type of chromatography, e.g. 16:4 which was overlapped by the major oleic acid. Not calculated peaks were estimated to one percent, which is probably too low according to our more recent results on the presence of acids of chain length 24 and higher. The values were calculated to within 0.1% in tables 2 and 3. The estimated accuracy of these values are: ±5 relative % for values of 10% and higher, ±10—20 relative % for values of 1.0 to 0.5 %.

The type of analysis presented is a compromise between time of analysis and amount of information obtained. The GLC-method is far quicker and more accurate than the earlier methods of fractional distillation, but complete separation and accurate determination of all the fatty acids present in a fish lipid in quantities between 0.05 to 2.00 % of the total, is a very time-consuming and careful task.

Polar versus non-polar lipids.

The general difference was one of unsaturation. It is known from other studies that phospholipids contain higher amounts of the highly unsaturated fatty acids than the corresponding triglycerides. This trend was clearly demonstrated in this analysis. All values for the acids 20:5 and 22:6 were higher for the polar fractions compared to the non-polar fractions. There was an average difference of 24 to 41% for fillet values, of 17.5 to 35.5% for liver values. Medium polyenes showed a less dramatic increase from 9 to 12%, while the values for 18:4 decreased from non-polar to polar fractions. Further, palmitic acid, 16:0 was higher in all phospholipid fractions compared to triglyseride fractions, with an average increase from 13.5 to 20%. The three acids 16:0, 20:5 and 22:6 are found mainly in position 2 in glycerides, and may have particular functions in phospholipid metabolism. (Malins & Wekell, 1969)). The tables show that the increase in 16:0, 20:5 and 22:6 were balanced mainly with decreases in the monoenoic acids.

All values for monoenoic acids were lower in polar than in non-polar fractions with the values for 18:1, oleic acid, mostly pronounced. Average

decreases for total monoenes were from 41 to 18% for filet samples and from 48 to 25% for liver samples.

Liver versus fillet lipids.

Differences between liver and fillet lipid fatty acid composition were more diffuse. The general picture was one of pronounced similarities within species. Somewhat higher averages for monoenes in liver samples than in filet samples were balanced with correspondingly lower values for the polyenes, particular for 20:5 and 22:6. This may be caused by the higher fat content of the livers compared to the filets, giving a more typical fat depot composition in the liver samples. The average values for liver triglycerides agreed well with the typical cod liver oil fatty acid composition (LAMBERTSEN & BRÆKKAN, 1965a), with the exception of the high value for 18:1, (40%) for redfish liver triglycerides. The fillet lipids did not correspond to herring oils and similar industrial body oils, but had half the percentage of 14:0 and a ratio of 1.4 for 16:0 to 16:1, compared to 2.0 for most herring oils. A comparison of pelagic versus bottom feeding habits may be pertinent in this context.

Differences and similarities between the four species investigated.

The four species have all rather similar size and feeding habits. Catfish eat mussels and echinoderms to some extent, and redfish may have a more pelagic feeding. Some fatty acids may deserve comments.

The plaice showed highest values for the 16-acids, 16:0 and 16:1, for all fractions. These were balanced with lower values for the polyenes and gave the fat a generally lower unsaturation. Oleic acid, 18:1, was particularly high in redfish liver triglycerides, partly balanced by lower values for the saturated fatty acids.

The high values for 20:3 + 4, from 4.2 to 11%, with the exceptions of the redfish samples and the plaice triglyceride sample are of some interest. The major part of this composite peak could be identified as arachidonic acid, 20:4 ω6, which overlaps with 20:3 ω3. This essential fatty acid arise from dietary 18:2 ω6, linoleic acid. Bottom feeding fishes may take in green algae with the stomach contents of their food animals. Particularly the catfish' diet of mussels should give a steady intake of green algea containing linoleic acid which is converted to arachidonic acid in the liver. The redfish lipids correspond more to the "normal" fish lipids, with 1 to 3% of ω6 acids.

Lastly it may be noted that the values for oddnumbered and branch chain acids are on the average higher in catfish lipids than in the lipids of the other three species.

SUMMARY

1. "Non-polar" (triglyceride and steryl esters) and "polar" (phospholipids) lipid fractions were prepared from liver and fillet tissues from four fish species. The four species — catfish, plaice, redfish and wrasse — were all known to have fat depots in both liver and fillet. The livers had from 10 to 28% fat, whereas the fillet had from 1.5—4% fat. The last values are somewhat low.
2. Fatty acid methyl esters were prepared from the 16 lipid fractions and analysed by gas liquid chromatography. Hydrogenated esters were also analysed to ensure good chain length determinations. Identification of minor polyunsaturated fatty acids was not attempted. The results were compared and commented on.
3. All values for the acids 16:0, 20:5 and 22:6 were higher in the phospholipid fractions than in the triglyceride fractions. The average sums for the three acids were 57% in the phospholipids and 33% in triglycerides. Correspondingly all values for the monoenoic acids 16:1, 18:1, 20:1 and 22:1 were lower in the phospholipid fractions than in the triglyceride fractions. The average totals for these acids were 21% in the phospholipids and 44% in the triglycerides.
4. The average fatty acid composition of the liver samples and the fillet samples were similar, and this study did not point to a typical "liver fat" as opposed to a "fillet fat" in fish. The small differences noted may relate to the much higher deposition of fat in livers than in fillets in the analysed samples. Generally, the present analyses showed a better similarity to the fatty acid composition of cod liver oil, than to herring oils and other industrial body oils. It is suggested that this points more to influences of feeding habits, pelagic versus bottom feeders, that is, different diets, than to species or organ differences of the fish.
5. Some minor differences in fatty acid compositions between the four fish species were noted. Of particular interest was the presence of up to 10% arachidonic acid in some of the samples, probably derived from dietary linoleic acid from algae taken in by these bottom feeding fish species.

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