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FATTY ACID COMPOSITIONS OF FISH FATS. COMPARISONS BASED ON EIGHT FATTY ACIDS.[1]

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ABSTRACT

74 samples of 34 different fish species and fish byproducts were analyzed for the fatty acid composition of their total lipids. This was a part of a total survey of nutrients in these samples. The contents of 8 major fatty acids are given in tables as percentages of the total fatty acids in the lipids, and discussed as 4 pairs. This presentation form was given to simplify comparisons between marine lipids. For the same purpose, the following 3 ratios are discussed: 1: The long chain to medium chain ratio (20:1 + 22:1 + 20:5 + 22:6/14:0 + 16:1 + 16:0 + 18:1), 2: The ratio between «dietary» and «structural» fatty acids (14:0 + 16:1 + 20:1 + 22:1/16:0 + 18:1 + 20:5 + 22:6) and 3: The monoene ratio 22:1/20:1.

INTRODUCTION

A project on the analysis of nutrients in Norwegian fish species and fish products was sponsored by the Norwegian Council for Fisheries Research for the years 1973–1975. During these years 83 samples of 35 different products were collected and analyzed for general composition, amino acids, fatty acids, vitamins and minerals. The results are published at intervals in «Fiskets Gang» (UTNE, 1976). The fatty acid composition of the lipids from this material is given and compared in the present paper.

Fish oils have been characterized using «values» such as saponification value, iodine value and percentage unsaponifiable matter, and these have sufficed in practical handling of fish oils up to recent times. Gas chromatography of fatty acid methyl esters makes highly detailed information easily accessible. Application of capillary columns in GLC brings forth the complicated composition of fish oil fatty acids and may result in tables of 60 to 70 different acids (ACKMAN et al., 1972, 1975). Whereas such full information is

[1]) This report was presented in part at the American Oil Chemists' Society's 68th Annual Meeting, New York, 1977.

valuable for our understanding of the biochemistry of these lipids, it is too voluminous in a more practical dealing with fish fats. Most of the published tables of fatty acid composition give figures for less than 25 acids. A dozen acids make up more than 90% of the total in fish fats, and of these, eight acids can be discussed in four pairs as a basis of comparison. The present paper discusses reasons for the selection of these eight acids and gives their concentrations in the lipids of 74 samples comprising 34 different fish products.

SAMPLES AND METHODS

Information about fishing grounds and time of the catch were obtained for most of the samples analyzed. Some samples were taken from fish factories and from fish markets. Full details are published in the complete tables of nutrients (UTNE, 1976). Only samples representative for the product were used. The samples were carefully homogenized by several passes in a meat grinder at low temperatures and were stored in the freezer until analyzed.

The lipids were extracted in methanol/chloroform (1:3). A small aliquot (0.5 to 1 g) was saponified in methanol/KOH with pyrogallol and ascorbic acid added for protection. Unsaponifiable matter was removed by ethyl ether extraction, whereafter HCl was added and the fatty acids were extracted with ethyl ether. Methylation followed immediately in methanol containing 12% borontrifluoride. The methylesters were taken up in hexane after vacuum evaporation of the solvent and purified by passage through a small column of alumina, again evaporated and weighed. An aliquot of the esters was fully hydrogenated using palladium on carbon as catalyst. Five percent solutions in hexane of the fatty acid methyl esters were stored in the freezer until GLC.

Details of the methods are given by LAMBERTSEN (1972).

GAS-LIQUID-CHROMATOGRAPHY.

Instrument: PERKIN-ELMER 900.
Columns: 6', 1/8" stainless steel.
Stationary phases: 15% of either OV-101 or EGSS-X on silanized Chromosorb. (SUPELCO).
Carrier gas: Nitrogen.
Temperature range: 160–210° centigrade.

Identification of peaks: Standards of saturated acids, monoenes and C-18 unsaturated acids (NU–CHEK). Further, semilog plots and general experience in fish fatty acids.

Quantitation: On-line computer (WANG 2200) using a programme for peak-separations and base line corrections. The fully hydrogenated methylesters run on OV-101 gave the concentrations of each chainlength, and the original methylesters run on EGSS–X gave the relations between the acids of different saturation within each chainlength. Values for 17 different fatty acids were calculated to 95%, adding 5% as non-calculated acids. This corresponded to the average sum of the 17 acids given by the computer program.

RESULTS AND DISCUSSION

Samples of fish species and products were grouped according to their total fat contents into a high-fat, a medium fat and a low fat group. Table 1 gives values from the high fat group (ave. 12.7% fat) comprising 22 samples of 8 small, pelagic fish species used for the production of fish meal and oil. The pearlsides (Maurolicus mulleri, 6–7 cm) may be exploited in the future. Table 2 gives results from medium fat fish species, among which are samples of 3 of the smaller cod species, and further from some samples of medium fat fish byproducts. This group totals 22 samples with an average fat content of 5.4%. In Table 3 are collected results from 18 samples with fat contents mostly below 1% (average 0.7%). These comprise byproducts and gutted fish of the cod family, a fish family having their fat stores exclusively in the liver.

Finally, Table 4 gives results from 6 samples of prawn (shrimp) offall and from 6 krill samples. The former is a byproduct used as a feed component in fish farming, and the latter a small crustacean species of great potential value as food and feed.

The tables give fatty acid percentages in the total lipids of each sample. Only eight of the fatty acids calculated are given, but these add up to 84% (73–90%) and are the dominant acids in all marine lipids. They are shown as four pairs as discussed below.

14:0 + 16:1.[1]) Myristic and palmitoleic acids are the lower homologues of palmitic and oleic acids. They are found in all fish fats, and are characteristic for the pelagic, shoaling fish species exploited for fish meal and oil production. They are found in highest levels in the triglycerides were they represent 5–10% each. Probably, 14:0 and 16:1 originate in marine phytoplanctonic algea (BROCKERHOFF & al., 1964). Table 5, giving averages from Tables 1 to 3, shows levels of 4 to 10% of both 14:0 and 16:1 in the high-fat samples, decreasing with the average fat content of the groups. The samples from Table 3, mostly with less than 1% lipid, have in effect very

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[1]) 16:1, a chainlength of 16 carbon atoms and one double bond.

Table 1. Major fatty acids (%) in high – fat pelagic fish species.

Sample of	Obtained Month-year	% Fat	14:0	16:1	16:0	18:1	20:1	22:1	20:5	22:6	Sum	R_1	R_2	R_3
Capelin	1–73	14,1	7,1	11,0	9,9	13,4	16,3	12,6	8,6	6,7	85,6	1,07	1,21	0,77
»	2–73	13,8	6,7	10,6	10,6	14,2	15,2	11,7	9,0	6,7	84,7	1,01	1,09	0,77
»	3–73	4,0	7,3	8,3	9,7	14,5	13,6	10,4	9,2	11,0	84,0	1,11	0,89	0,76
»	8–73	12,5	6,7	8,8	10,7	15,4	10,8	10,8	11,4	10,7	85,3	1,05	0,76	1,00
Polar cod	10–73	8,1	6,1	8,2	9,1	11,1	17,2	14,5	9,8	8,4	84,4	1,45	1,19	0,84
»	5–75	8,6	5,6	8,6	11,7	14,2	18,5	17,9	5,1	3,6	85,2	1,12	1,46	0,97
Silver smelt, great	4–73	5,7	5,5	4,3	9,7	14,3	13,8	22,3	5,8	9,6	85,3	1,52	1,16	1,62
»	6–74	4,2	6,3	4,3	14,0	17,1	11,9	17,6	6,1	9,5	86,8	1,08	0,85	1,48
»	12–74	10,0	6,6	5,7	13,3	16,3	12,3	18,5	5,8	7,8	86,3	1,06	0,99	1,50
Horse mackerel	5–74	12,6	6,8	4,7	15,6	12,9	11,2	19,2	4,8	8,2	83,4	1,09	1,00	1,71
Mackerel	7–74	11,0	7,0	5,3	14,4	12,3	12,7	19,4	5,0	7,5	83,6	1,14	1,13	1,53
»	10–74	23,7	8,0	5,2	13,4	12,0	12,1	17,4	5,1	9,5	82,7	1,14	1,06	1,44
Herring, North Sea	10–74	14,1	7,7	6,6	14,4	13,6	13,6	20,8	6,4	6,2	89,3	1,11	1,19	1,53
Herring, local	7–74	23,5	7,9	6,5	13,4	8,7	13,6	18,6	7,2	8,5	84,4	1,31	1,23	1,37
»	10–74	15,8	7,7	6,3	13,1	10,1	11,8	19,9	6,4	9,8	85,1	1,29	1,15	1,69
»	11–75	14,4	9,9	5,6	16,3	10,2	15,2	27,0	1,7	1,1	87,0	1,07	1,96	1,78
Sprat	1–74	12,9	5,5	5,8	17,5	18,0	7,4	12,8	7,4	11,7	86,1	0,84	0,57	1,73
»	2–74	10,6	4,8	5,5	16,5	19,2	7,2	13,7	7,2	11,7	85,8	0,87	0,57	1,90
Pearlsides, Müllers	10–73	12,8	7,2	4,1	9,5	6,3	11,1	18,7	5,6	13,9	76,4	1,82	1,16	1,68
»	1–75	18,8	7,7	4,7	15,2	9,7	12,0	20,7	5,7	10,0	85,7	1,30	1,11	1,73
»	5–75	8,7	7,6	5,5	14,4	10,4	14,4	28,4	2,4	3,6	86,7	1,29	1,81	1,97
»	11–75	18,4	5,3	6,9	17,0	14,8	6,7	14,4	8,2	11,2	84,5	0,92	0,65	2,15
Averages of 22 values		12,7	6,9	6,5	13,2	13,1	12,7	17,6	6,5	8,5	84,9	1,17	1,10	0,85–1,68
+ S.D.		5,3	1,1	2,0	2,7	3,2	3,0	4,8	2,3	3,0	2,4	0,22	0,34	0,11–0,21

low triglyceride contents, and the major part of the extracted lipids consists of phosholipids. Marine phospholipids have low levels of the 14:0 and 16:1 acids (LAMBERTSEN, 1972, 1973). Values of 6 to 9% for 14:0 and 5 to 11% for 16:1 (Table 1) correspond well with the composition of herring oils from different parts of the world (LAMBERTSEN and BRAEKKAN, 1965 B), and with fish oils from the North Sea (HØLMER, 1967). The cod fishes have their fat depots in the liver, and the two fatty acids represent somewhat lower proportions of the fat (Table 2). Cod liver oil contains 3% 14:0 and 9% 16:1 (LAMBERTSEN and BRAEKKAN, 1965 A).

16:0 + 18:1. Palmitic and oleic acids are the major end products of fatty acid biosynthesis and are present in all fats. Fish oils contain major fatty acids of chain lengths 20 and 22, and therefore somewhat lower levels of 16:0 and 18:1. Particularly, the proportion of oleic acid may fall below 10% in some of the smaller fish species (Table 1). This low level probably originate in the food chain, as many marine evertebrates have low levels of oleic acid in the fat (LAMBERTSEN, unpubl. results). Table 5 shows levels each averaging 13% for these two acids in high fat samples, increasing with decreasing fat contents to an average of 17–18% each. Values around 20% for both 16:0 and 18:1 are normally found in marine phospholipids.

The contents of the two pairs of fatty acids 14:0 + 16:1 and 16:0 + 18:1 vary inversely, giving a rather constant sum of 40% of the total fatty acids in marine fish lipids.

20:1 + 22:1. The two longchain monoene acids are present in all marine lipids and are major components in the fat from pelagic fish species in the Northern oceans. A small copepod crustacean, Calanus finmarchicus (Gunn.) is a feed organism of great importance for these fish species. Its lipid reserve consists of 60–80% of wax esters, the rest being triglycerides and phospholipids. The alcohols of these wax esters contain 50–60% of 20:1 + 22:1, whereas the fatty acids have a more «normal» composition (but with a high percentage of 14:0) (LAMBERTSEN and MYKLESTAD., 1971, PASCAL and ACKMAN, 1976). The long chain fatty alcohols are oxidized to the corresponding fatty acids during digestion by the fish. Triglycerides of herring (Clupea harengus) may have more than 40% of the total fatty acids as 20:1 and 22:1 (LAMBERTSEN and HANSEN to be published). In contrast, oils from other herring species ofGMid-Atlantic and South Atlantic origin contain less than 5% of these acids (LAMBERTSEN and BRAEKKAN, 1965 B). Table 5 shows a sum of 30% of 20:1 + 22:1 in high fat samples, decreasing to 17% in medium fat samples and 7% in low fat samples. The latter value corresponds to the low levels of 20:1 and 22:1 normally found in fish phospholipids. The table also shows a wider range for the 22:1 values (28 to 1%) than for the 20:1 values (19 to 3%).

20:5 + 22:6. These two highly unsaturated fatty acids are mainly re-

Table 2. Major fatty acids (%) in medium – fat fish species and fish products.

Sample of	Obtained Month-year	% Fat	14:0	16:1	16:0	18:1	20:1	22:1	20:5	22:6	Sum	R_1	R_2	R_3
Saithe, small	4–73	4,0	5,3	5,7	9,9	12,3	10,3	9,6	8,9	14,2	76,2	1,30	0,68	0,93
»	7–73	4,9	3,9	5,3	11,8	21,1	5,5	5,1	12,9	15,5	81,1	0,93	0,32	0,93
»	10–73	5,6	4,7	7,1	16,8	20,2	7,8	5,8	10,3	11,7	84,4	0,73	0,43	0,74
Blue whiting	2–73	7,4	3,9	6,1	11,5	14,8	10,7	12,4	10,4	12,6	82,4	1,27	0,67	1,16
»	4–73	3,5	3,8	5,0	12,1	16,2	8,3	9,9	9,6	16,7	81,6	1,20	0,49	1,19
»	8,73	3,7	5,0	4,9	12,4	16,5	9,7	10,7	7,7	15,4	82,3	1,12	0,58	1,10
Norway pout	3–73	2,4	4,9	3,9	11,0	12,9	8,2	12,5	7,2	20,7	81,3	1,49	0,56	1,52
»	3–73	2,3	6,5	4,2	10,9	12,1	9,5	9,7	7,0	19,7	79,6	1,36	0,60	1,02
»	8–73	12,1	6,6	3,8	9,1	9,6	13,2	14,7	6,9	11,8	75,7	1,60	1,02	1,11
»	11–74	10,0	4,4	6,2	16,9	19,3	8,7	9,3	10,7	11,0	86,5	0,85	0,49	1,19
Ballan wrasse	5–73	4,9	2,9	8,5	11,6	21,4	4,0	1,4	11,7	11,2	72,7	0,64	0,30	0,35
» [1])	6–74	2,8	3,1	9,9	15,4	22,6	3,6	0,7	8,5	9,6	73,4	0,44	0,30	0,19
Lumpsucker, f.	3–74	1,8	5,6	4,2	8,6	20,6	12,8	13,6	8,5	12,7	86,6	0,92	0,56	0,87
» m.	3–74	3,8	6,5	4,3	10,2	22,8	10,5	9,1	10,2	10,3	83,9	0,92	0,56	0,87
Sprat	8–73	10,4	4,4	8,2	14,9	17,4	3,0	2,2	13,8	17,6	81,5	0,82	0,27	0,73
Sandeel	5–73	8,4	6,0	5,0	12,3	12,2	6,6	8,6	12,0	17,2	79,9	1,25	0,48	1,30
Basking shark, meat	8–73	6,3	4,9	9,3	10,9	22,9	9,4	4,1	3,3	13,5	78,3	0,63	0,54	0,44
Fish offal, unspec.	6–73	4,9	5,0	8,3	9,2	9,8	11,6	8,9	16,0	9,6	78,4	1,43	0,75	0,77
Saithe, offal	–73	3,3	7,7	7,1	12,8	15,4	6,9	5,0	11,2	12,1	78,2	0,82	0,51	0,72
»	10–73	6,3	3,1	3,9	12,6	20,9	5,0	3,8	11,3	18,7	79,3	0,96	0,24	0,76
Dogfish, heads	10–74	1,7	1,6	4,9	15,3	20,8	11,2	7,9	6,0	15,5	83,2	0,95	0,44	0,71
»	1–75	4,7	2,0	4,6	15,0	20,1	9,7	10,7	6,5	14,3	82,9	0,99	0,48	1,10
Averages of 21 samples		5,4	4,7	5,7	12,2	17,1	8.7	8,3	9,6	14,4	80,8	1,07	0,53	0,94
+ S.D.		2,9	1,5	1,7	2,4	4,3	2,8	3,7	3,0	3,2	3,5	0,28	0,18	0,28

[1]) excluded from averages.

Table 3. Major fatty acids (%) in low-fat fish products (Gadidae).

Sample of	Obtained Month-year	% Fat	14:0	16:1	16:0	18:1	20:1	22:1	20:5	22:6	Sum	R_1	R_2	R_3
Cod, heads	11–74	0,3	1,8	5,6	18,0	22,5	6,5	3,3	7,6	14,8	80,1	0,67	0,27	0,51
»	3–74	0,4	2,1	4,8	18,7	21,8	6,2	3,0	10,8	15,4	82,8	0,75	0,24	0,48
»	–75	0,4	1,9	3,6	16,3	19,9	5,7	3,0	11,5	23,3	85,2	1,04	0,20	0,53
Cod, backbones	–75	0,4	1,5	3,0	17,2	16,1	2,9	1,9	13,8	27,1	83,5	1,21	0,12	0,66
»	–75	0,5	1,7	3,6	18,7	17,3	5,0	1,7	11,5	24,7	84,2	1,04	0,16	0,34
Cod, roe	5–74	0,7	1,6	4,5	17,8	17,2	3,0	1,2	14,6	28,5	88,4	1,15	0,13	0,40
»	3–74	0,9	1,7	4,2	17,6	16,3	3,3	1,2	15,1	28,0	87,4	1,20	0,13	0,36
Cod, milt [1])	5–74	1,4	1,4	2,7	16,6	17,1	0,5	1,6	14,0	24,9	78,8	1,08	0,08	3,20
»	3–74	2,1	1,1	2,1	18,2	18,7	3,8	1,2	13,0	27,6	85,7	1,14	0,10	0,32
Cod, viscera	3–74	1,2	2,0	5,8	15,4	19,0	5,5	2,5	11,6	21,7	83,5	0,98	0,23	0,45
Saithe, heads	–75	0,6	1,5	4,0	19,1	21,1	5,2	2,4	9,5	20,5	83,3	0,82	0,18	0,46
Tusk, heads [1])	–75	0,8	2,5	7,0	17,3	29,6	10,9	4,5	5,0	10,0	86,8	0,54	0,40	0,41
Saithe, roe	2–75	0,5	1,2	4,0	18,5	18,5	3,7	3,7	11,7	29,4	90,7	1,15	0,16	1,00
Saithe, small, gutted	4–73	0,4	1,7	2,7	12,4	13,1	5,9	3,5	12,7	30,6	82,6	1,76	0,20	0,59
» [1])	7–73	0,5	2,1	2,0	11,9	13,7	2,4	0,4	12,8	32,3	77,6	1,61	0,09	0,17
»	10–73	0,5	1,4	2,7	19,0	17,9	4,3	2,3	12,0	25,7	85,3	1,08	0,14	0,53
Blue whiting, gutted	2–73	0,5	2,0	3,4	13,1	12,8	3,6	3,9	14,9	26,5	80,2	1,56	0,19	1,08
»	4–73	0,9	2,9	4,0	13,3	15,7	4,8	5,8	10,8	24,8	82,1	1,29	0,27	1,21
Averages of 15 values		0,7	1,7	3,9	16,9	17,9	4,6	2,7	12,1	24,6	84,3	1,12	0,18	0,59
+ S.D.		0,5	0,4	1,0	2,3	2,8	1,2	1,3	2,0	4,7	2,9	0,28	0,05	0,28

[1]) excluded from averages.

Table 4. Major fatty acids (%) in crustacean products.

Sample of	Obtained Month-year	% Fat	14:0	16:1	16:0	18:1	20:1	22:1	20:5	22:6	Sum	R_1	R_2	R_3
Prawn offal	6–73	2,3	5,2	10,6	12,7	19,0	5,3	7,7	13,3	11,3	85,1	0,79	0,51	1,45
»	3–74	2,9	4,8	7,7	12,7	20,2	10,6	12,1	9,9	9,7	87,7	0,93	0,67	1,14
»	3–74	1,8	4,2	9,0	13,1	22,1	8,0	8,3	11,8	10,1	86,6	0,79	0,51	1,04
» ¹)	3–74	0,3	2,9	7,3	15,0	22,6	5,1	4,9	16,3	12,3	86,4	0,81	0,30	0,96
» ¹)	11–74	0,5	2,5	10,9	12,8	22,5	4,6	2,0	21,7	9,7	86,7	0,78	0,29	0,43
»	11–74	1,8	2,8	13,1	11,9	23,1	7,3	3,1	17,9	7,8	87,0	0,71	0,43	0,42
Averages			3,7	9,8	13,0	21,6	6,8	6,4	15,2	10,2	86,6	0,80	0,45	0,91
+ S.D.			1,1	2,2	1,0	1,6	2,3	3,7	4,3	1,5	0,9	0,07	0,14	0,41
Krill, boiled	2–74	2,1	5,1	6,8	15,6	15,3	7,1	8,9	15,0	13,8	87,6	1,05	0,46	1,25
» fresh	2–74	1,7	4,8	3,6	13,3	15,2	9,5	17,4	9,6	15,0	88,4	1,40	0,66	1,83
» boiled	3–75	1,0	2,8	4,4	18,5	16,0	2,5	2,8	18,7	18,0	83,7	1,01	0,17	1,12
» fresh	3–75	1,0	3,0	4,6	19,4	16,0	2,2	2,8	18,4	17,3	83,7	0,95	0,17	1,27
» boiled²)	–75	5,1	6,3	5,5	18,0	17,7	1,5	1,2	20,5	15,0	85,7	0,80	0,20	0,80
» fresh²)	–75	8,6	8,1	6,9	18,2	18,0	1,6	1,3	18,8	11,8	84,7	0,65	0,26	0,81
Averages			5,0	5,3	17,2	16,4	4,1	5,7	16,8	15,2	85,6	0,98	0,32	1,18
+ S.D.			2,0	1,3	2,3	1,2	3,4	6,4	4,0	2,3	2,0	0,26	0,19	0,38

¹) Machine shelled

²) Samples from Antarctic Sea.

sponsible for the high iodine value which characterizes most fish oils and for their high tendency to go rancid. They belong to the ω-3 or (n ÷ 3) series of polyenoic acids as do most of the marine lipid polyenes. They are particularly abundant in fish phospholipids where they may reach 50–60% of the total fatty acids (LAMBERTSEN and HANSEN, to be published). Table 5 shows an average sum of 37% of 20:5 + 22:6 in low fat samples, decreasing to 24% in medium fat samples, and to 15% in the high fat samples. As for the preceding fatty acid pair, there is a greater range of values for 22:6, from 1 to 31%, than for 20:5, from 2 to 16%. The two long-chain pairs, 20:1 + 22:1 and 20:5 + 22:6 vary inversely, the sum being approximately 43%.

OTHER FATTY ACIDS

Detailed analysis shows the complexity of fish lipid fatty acid composition. The present analyses gave 17 values for each sample, of which only 8 are given in the tables. Most of the other acids are present in percentages below 2% each, and only a few are among those generally discussed in composition studies. Stearic acid, 18:0, is normally found at levels of 1.5–3% in fish lipids. The polyenoic acid 18:4 may be found as major acid at 3–6%, but this acid does not seem to vary relatively to 20:5 and 22:6. Problems of overlapping peaks in conventional short GLC columns have reduced the reliability of the 18:4 values. The pair 18:2 + 20:4 (n ÷ 6) is of importance in animal lipids as essential fatty acids (EFA), but fish lipids contain only low levels of (n ÷ 6)-acids and are not considered as sources of EFA. Most polyenoic acids in marine lipids are in the (n ÷ 3)-family, and among these only the fully unsaturated acids 18:4, 20:5 and 22:6 are found as major acids (> 2%).

CRUSTACEAN PRODUCTS

Table 4 gives values for samples of prawn offall and for krill. The fatty acid composition of these samples differ little from most marine lipids. The wide range of values for 22:1 may be noted. The zooplanctonic copepod Calanus finmarchicus, «red feed» was included in the original survey, but as the greater part of the lipid in this organism consists of wax esters, the triglyceride values are of little interest and were not includes in Table 4.

FATTY ACID RATIOS

As most fatty acid compositions are given on percentage basis of the total acids determined, all values are relative. As a consequence, ratios between single fatty acids or groups may give additional useful information. The ratio between 20:3 (n ÷ 9) and 20:4 (n ÷ 6) has been useful in ascertaining

Table 5. Summations of tables 1, 2 and 3.

	% Fat	14:0+16:1	16:0+18:1	20:1+22:1	20:5+22:6	R_1	R_2	R_3	
Average	12,7	6,9+ 6,5	13,2+13,1	12,7+17,6	6,5+ 8,5	1,17	1,10	0,85 1,68	22
Min. val.	4,0	4,8 4,1	9,1 6,3	6,7 10,4	1,7 1,1	0,84	0,57	0,76 1,37	high-fat
Max. val.	23,7	9,9 11,0	17,5 19,2	18,5 28,4	11,4 13,9	1,82	1,96	1,00 2,15	samples
Sum	–	13,4	26,3	30,3	15,0	—	—	— —	
Average	5,4	4,7+ 5,7	12,2+17,1	8,7+ 8,3	9,6+14,4	1,07	0,53	0,94	21
Min. val.	1,7	2,0 3,8	8,6 9,6	3,0 2,2	3,3 9,6	0,63	0,24	0,35	medium-
Max. val.	12,1	7,7 9,3	16,9 22,9	13,2 14,7	16,0 20,7	1,60	1,02	1,52	fat
Sum	–	10,4	29,3	17,0	24,0	—	—	—	samples
Average	0,7	1,7+ 3,9	16,9+17,9	4,6+ 2,7	12,1+24,6	1,12	0,18	0,59	15
Min. val.	0,3	1,1 2,1	12,4 12,8	2,9 1,2	7,6 14,8	0,67	0,10	0,32	low-fat
Max. val.	2,1	2,9 5,8	19,1 22,5	6,5 5,8	15,1 30,6	1,76	0,27	1,21	samples
Sum	–	5,6	34,8	7,3	36,7				

the EFA-status of a given tissue (HOLMAN et al., 1964). KONDO (1975) used different fatty acid ratios the explore relations between the iodine values and fatty acid compositions of Okhotsk herring lipids.

Three ratios were tried out on the present analyses and are given in Tables 1–5. The first, R_1, gives the relation between the four long-chain acids (20:1 + 22:1 + 20:5 + 22:6) and the four medium chain acids (14:0 + 16:1 + 16:0 + 18:1). It corresponds to some extent to the saponification value of the total fatty acids. The average of R_1 was 1.12 for the samples of fish species and products, i.e. they contained a higher percentage of the long-chain acids than the medium chain acids. It has already been pointed out that both the two long-chain pairs and the two medium chain pairs varied inversely and showed fairly constant sums of 43% and 40% respectively, i.e. $R_1 \sim 1.1$. There was, however, a fairly wide range of values for the ratios R_1, from about 2:3 to 3:2. A third of the values fell below 1, but some of these may have too low values for 22:6 because of oxidation during the handling of the samples. Other samples, as those of sprat, have higher than average values of oleic acid, 18:1.

The ratio R_2 relates the «dietary» fatty acids 14:0 + 16:1 + 20:1 + 22:1 to the «structural» fatty acids 16:0 + 18:1 + 20:5 + 22:6. This relation must be seen as an approximation only, and the ratio may also be related to triglyceride versus phospholipid content of the fat. The ratio is clearly related to the fat content of the fish samples. An increasing triglyceride depot in the fish parallels increasing percentages of the acids 14:0, 16:1, 20:1 and 22:1, and it seems reasonable that these acids are characterized as «dietary».

Table 5 shows a value for R_2 of 0.2 (0.1–0.3) in the low-fat samples, increasing to 0.5 (0.2–1) in the medium-fat samples, and further to 1.1 (0.6–2) in the high-fat samples. Tables 1 to 3 show that R_2 does not characterize specific samples of fish species and products within each fat-group. The ratio gave more information in a study of different tissue lipids in three high-fat fish species (LAMBERTSEN and HANSEN, to be published).

Finally was tried the ratio R_3 between the contents of 22:1 and 20:1. As discussed above, these two acids are probably derived from the intake of wax esters in the food containing 20:1 and 22:1 alcohols. The two may be differently metabolized by the fish. Table 5 shows widely varying R_3-values in low- and medium-fat samples (0.3–1.5). Two groups separated out in the high-fat samples. All samples of capelin and polar cod lipids, e.g. fish species from the Barents Sea had R_3-values below 1 (0.8–1). The average content of 22:1 was 13%, whereas the average for the whole group was 17.6%. Correspondingly, the 20:1-content was 15.3% as compared to 12.7% for the whole group. The other samples in the high-fat group were caught in the North Sea or off the south-western coast of Norway, and had R_3-values between 1.4 and 2.2.

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