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Effects of cooking on the fatty acids of three freshwater fish species

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The effects of cooking on the fatty acid concentrations and the stability of long chain *n*-3 fatty acids in fish flesh were studied. The cooking methods used were boiling, baking in the normal and microwave oven and frying with sunflower and rapeseed oils. Three freshwater fish species (rainbow trout, vendace and pike) with different sizes and lipid contents were studied. The concentrations of long chain *n*-3 fatty acids in fish flesh increased in most cases due to the cooking process. This was mostly caused by the loss of moisture. However, in baked and microwave-cooked vendace their concentrations increased about 70% even when calculated on a dry weight basis. Frying oils were efficiently absorbed into lean vendace and pike, and to some extent into medium fatty rainbow trout. The absorption of *n*-6 fatty acids from cooking oils may interfere with the biological effects of *n*-3 fatty acids.

INTRODUCTION

The effects of long chain *n*-3 fatty acids on lipid metabolism have been extensively studied in the last decade (Harris, 1989; Kinsella *et al.*, 1990). These fatty acids (FAs) have been shown to modify *n*-6 polyunsaturated fatty acid (PUFA) metabolism (Kinsella *et al.*, 1990). These changes may be of importance in prevention of cardiovascular disease (Leaf, 1990). Fish and other aquatic foodstuffs are the major sources of long chain *n*-3 FAs in human nutrition. The fatty acid compositions of raw fish have been widely studied (Ackman, 1989). However, the number of reports concerning the effects of cooking on the stability of *n*-3 FAs is limited (Mai *et al.*, 1978; Gall *et al.*, 1983; Dudek & Elkins, 1986; Hearn *et al.*, 1987). We have found earlier that boreal freshwater fish species contain considerable amounts of *n*-3 FAs (Ågren *et al.*, 1987). Diets containing these fishes were also found to modify lipid metabolism in human subjects (Ågren *et al.*, 1988, 1990).

The aim of this study has been to examine how different cooking methods affect FA concentrations of fish flesh. Three important species in Lake-Finland with different sizes and fat contents were selected for these experiments.

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MATERIALS AND METHODS

Preparation of samples

Rainbow trout (*Oncorhynchus mykiss*), vendace (*Coregonus albula*) and pike (*Esox lucius*) were studied. Fresh fish (caught on the same day) were obtained from the local market. They were gutted and washed and stored at −20°C until used for the experiments within 3 months. We have found that the fatty acid compositions of fish flesh do not change within this storing period despite the slightly increased lipid peroxide values (unreported data).

Pike and rainbow trout were filleted and cut up to pieces of 50–85 g (pike) or 95–120 g (rainbow trout) before cooking. Skin was not removed but pikes were scaled. Vendace was used as the whole fish after evisceration (10–20 g). Fish samples were cooked in boiling water (6 min for vendace and 10 min for rainbow trout and pike), baked in the oven (175°C, 15 and 25 min), cooked in the microwave oven (2475 MHz, 1 and 2 min) and fried (about 160°C, 3 min per side). Cooking was done in the regular way as when preparing fish for a meal, but no salt or additional ingredients were added. Sunflower oil (about 20% oleic acid and 70% linoleic acid) and rapeseed oil (about 60% oleic acid, 20% linoleic acid and 10% α-linolenic acid) were used in frying (5 g for pike and rainbow trout pieces and 3 g for vendace). Five samples from each species were cooked in each method. Rainbow

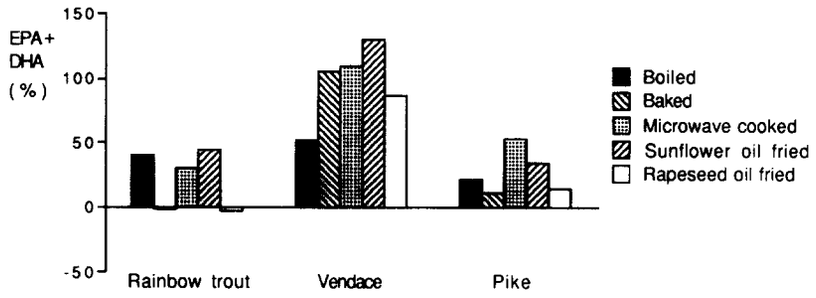

Fig. 1. The percentage changes in the sum of eicosapentaenoic and docosahexaenoic acid (EPA + DHA) during different cooking methods in rainbow trout, vendace and pike flesh.

trout and pike fillet pieces used in one cooking method were from the same fish.

Flesh samples for fatty acid analyses were taken before and after the cooking from the same fillet piece (rainbow trout and pike) or fish (vendace). A small hole (1–3 g) was cut so that the tissues under the skin and near the backbone were equally represented. In rainbow trout and pikes at least 2 cm were left between the sample holes made before and after cooking. The samples of vendace were taken from the opposite sides of fish. Skin was removed and the sample was minced. About 0·3 g of minced sample was weighed and extracted with chloroform–methanol (2 : 1 (v/v)) by the method of Folch *et al.* (1957). Chloroform (6 ml) contained 250 μg heptadecanoic acid methyl ester (17 : 0) as an internal standard.

Moisture was determined by drying weighed samples at 100°C to constant weight.

Fatty acid analyses

Fatty acids were transmethylated with 0·5 mol/litre sodium methoxide in methanol. Fatty acid methyl esters were analysed by Varian 3700 gas chromatograph (Varian Associates, Palo Alto, USA) equipped with a 25 m × 0·32 mm i.d. (film thickness 0·25 μm) fused silica capillary column (NB-351; HNU-Nordion Ltd, Helsinki, Finland). The oven temperature was programmed from 60°C to 250°C at 10°C/min. Injector and flame ionization detector temperatures were 250°C and 260°C, respectively. The samples were injected manually with the splitless injection technique. The chromatograms were recorded with a Shimadzu C-R6A integrator (Shimadzu Corporation, Kyoto, Japan). Quantitative analyses were made by comparing the peak areas with heptadecanoic acid methyl ester. To compensate for the differences in response of the gas chromatographic system, the response factors for individual fatty acids were determined using fatty acid standard mixtures.

RESULTS

The effects of different cooking methods on FA concentrations and moisture in fish flesh are presented in Tables 1–5 (see below). The percentage changes in

Table 1. Fatty acid concentrations (mg/100 g) and moisture (%) in raw and boiled fish flesh (mean ± SD, *n* = 5)

Fatty acid	Rainbow trout		Vendace		Pike	
	Raw	Cooked	Raw	Cooked	Raw	Cooked
14 : 0	91 ± 25	176 ± 66	20 ± 14	47 ± 8	2 ± 1	2 ± 1
16 : 0	385 ± 97	674 ± 225	130 ± 46	229 ± 36	75 ± 11	99 ± 16
18 : 0	87 ± 21	147 ± 49	36 ± 11	57 ± 7	21 ± 2	25 ± 3
16 : 1*n*-(7+9)	158 ± 44	304 ± 112	36 ± 27	88 ± 15	4 ± 2	7 ± 3
18 : 1*n*-(7+9)	525 ± 141	974 ± 359	76 ± 39	114 ± 20	39 ± 8	54 ± 12
20 : 1*n*-(9+11)	182 ± 49	340 ± 127	—	—	—	—
22 : 1*n*-(9+11)	181 ± 53	335 ± 118	—	—	—	—
18 : 2*n*-6	124 ± 33	246 ± 88	16 ± 8	37 ± 5	5 ± 1	10 ± 3
18 : 3*n*-3	34 ± 9	67 ± 22	21 ± 12	53 ± 11	2 ± 1	4 ± 1
18 : 4*n*-3	36 ± 11	70 ± 26	12 ± 10	32 ± 6	—	—
20 : 3*n*-3	5 ± 2	8 ± 3	—	—	—	—
20 : 3*n*-6	6 ± 2	11 ± 4	—	—	—	—
20 : 4*n*-3	42 ± 11	73 ± 22	10 ± 5	21 ± 3	—	—
20 : 4*n*-6	17 ± 4	27 ± 8	47 ± 15	81 ± 12	13 ± 1	14 ± 2
20 : 5*n*-3	181 ± 42	287 ± 74	80 ± 30	139 ± 24	32 ± 4	40 ± 6
22 : 4*n*-6	—	—	7 ± 3	13 ± 1	—	—
22 : 5*n*-3	86 ± 19	136 ± 38	21 ± 7	39 ± 4	10 ± 2	12 ± 2
22 : 5*n*-6	8 ± 1	13 ± 3	22 ± 7	34 ± 6	4 ± 1	5 ± 1
22 : 6*n*-3	615 ± 130	837 ± 179	208 ± 47	299 ± 28	202 ± 20	245 ± 27
Total	2763 ± 661	4725 ± 1513	742 ± 265	1313 ± 167	409 ± 49	517 ± 73
Moisture	73·8 ± 0·8	68·6 ± 1·0	78·9 ± 0·8	74·6 ± 1·2	78·8 ± 0·5	76·4 ± 1·3

Table 2. Fatty acid concentrations (mg/100 g) and moisture (%) in raw and baked fish flesh (mean ± SD, *n* = 5)

Fatty acid	Rainbow trout		Vendace		Pike	
	Raw	Cooked	Raw	Cooked	Raw	Cooked
14:0	171 ± 93	176 ± 94	11 ± 3	48 ± 20	2 ± 1	2 ± 0
16:0	630 ± 289	618 ± 255	94 ± 13	216 ± 75	49 ± 3	62 ± 6
18:0	125 ± 48	118 ± 47	25 ± 3	61 ± 20	17 ± 2	19 ± 2
16:1*n*-(7+9)	266 ± 140	250 ± 123	20 ± 9	94 ± 42	3 ± 1	6 ± 2
18:1*n*-(7+9)	774 ± 396	706 ± 328	48 ± 19	162 ± 91	30 ± 4	35 ± 6
20:1*n*-(9+11)	267 ± 133	236 ± 106	—	—	—	—
22:1*n*-(9+11)	256 ± 121	226 ± 100	—	—	—	—
18:2*n*-6	217 ± 111	205 ± 98	8 ± 3	34 ± 14	7 ± 1	8 ± 1
18:3*n*-3	61 ± 31	60 ± 28	11 ± 4	45 ± 16	3 ± 1	3 ± 1
18:4*n*-3	74 ± 38	76 ± 39	7 ± 3	31 ± 10	—	—
20:3*n*-3	10 ± 5	10 ± 6	—	—	—	—
20:3*n*-6	12 ± 6	11 ± 5	—	—	—	—
20:4*n*-3	82 ± 41	75 ± 26	7 ± 2	21 ± 7	—	—
20:4*n*-6	23 ± 9	23 ± 8	31 ± 6	73 ± 20	11 ± 1	13 ± 2
20:5*n*-3	272 ± 118	270 ± 106	46 ± 11	117 ± 33	15 ± 2	18 ± 3
22:4*n*-6	—	—	4 ± 1	10 ± 2	—	—
22:5*n*-3	104 ± 46	100 ± 34	15 ± 4	40 ± 11	12 ± 1	14 ± 2
22:5*n*-6	11 ± 3	12 ± 3	17 ± 4	40 ± 10	2 ± 0	4 ± 1
22:6*n*-3	729 ± 259	710 ± 207	154 ± 29	297 ± 64	144 ± 14	160 ± 18
Total	4084 ± 1882	3882 ± 1604	498 ± 108	1289 ± 427	295 ± 29	344 ± 41
Moisture	73·1 ± 2·2	69·4 ± 2·9	77·9 ± 0·8	73·4 ± 1·1	80·1 ± 0·2	77·9 ± 0·9

eicosapentaenoic acid (EPA, 20 : 5*n*-3) and docosahexaenoic acid (DHA, 22 : 6*n*-3) concentrations during cooking are shown in Fig. 1.

Boiling

The total concentration of FAs increased about 70%, in both rainbow trout and vendace, and 26% in pike due to boiling (Table 1). In all three species, the greatest increase was found in 18-carbon PUFAs, while smaller increases were observed in longer chain PUFAs, especially in DHA. The amounts of monounsaturated FAs (MUFAs) were also increased more than average.

Baking in the oven

About 5% decrease of the total content of FAs took place in rainbow trout (Table 2). This reduction was

Table 3. Fatty acid concentrations (mg/100 g) and moisture (%) in raw and microwave-cooked fish flesh (mean ± SD, *n* = 5)

Fatty acid	Rainbow trout		Vendace		Pike	
	Raw	Cooked	Raw	Cooked	Raw	Cooked
14:0	149 ± 61	203 ± 98	10 ± 5	71 ± 21	4 ± 1	3 ± 2
16:0	629 ± 220	835 ± 344	91 ± 18	257 ± 68	47 ± 12	75 ± 10
18:0	132 ± 44	175 ± 69	25 ± 6	71 ± 18	18 ± 2	23 ± 2
16:1*n*-(7+9)	237 ± 96	320 ± 150	16 ± 9	126 ± 35	4 ± 1	6 ± 1
18:1*n*-(7+9)	750 ± 287	1007 ± 452	43 ± 14	200 ± 62	32 ± 1	42 ± 4
20:1*n*-(9+11)	259 ± 98	346 ± 159	—	—	—	—
22:1*n*-(9+11)	237 ± 91	323 ± 146	—	—	—	—
18:2*n*-6	204 ± 78	257 ± 117	10 ± 5	59 ± 18	5 ± 1	8 ± 1
18:3*n*-3	52 ± 21	70 ± 30	12 ± 6	71 ± 22	2 ± 0	3 ± 0
18:4*n*-3	61 ± 25	82 ± 37	7 ± 6	51 ± 17	—	—
20:3*n*-3	7 ± 3	11 ± 4	—	—	—	—
20:3*n*-6	9 ± 4	12 ± 5	—	—	—	—
20:4*n*-3	53 ± 18	68 ± 27	7 ± 2	29 ± 6	—	—
20:4*n*-6	20 ± 6	26 ± 9	31 ± 7	87 ± 20	13 ± 2	20 ± 1
20:5*n*-3	225 ± 75	300 ± 114	52 ± 12	155 ± 33	21 ± 1	35 ± 5
22:4*n*-6	—	—	4 ± 1	14 ± 4	—	—
22:5*n*-3	84 ± 30	111 ± 45	15 ± 4	51 ± 10	6 ± 1	10 ± 1
22:5*n*-6	16 ± 4	16 ± 6	18 ± 4	44 ± 7	3 ± 1	3 ± 0
22:6*n*-3	715 ± 195	923 ± 293	178 ± 26	333 ± 64	146 ± 29	223 ± 14
Total	3839 ± 1354	5085 ± 2102	520 ± 119	1619 ± 394	301 ± 55	451 ± 37
Moisture	71·1 ± 1·9	66·3 ± 4·0	78·8 ± 1·6	73·2 ± 1·8	78·9 ± 1·3	74·7 ± 0·9

Table 4. Fatty acid concentrations (mg/100 g) and moisture (%) in raw and sunflower oil–fried fish flesh (mean ± SD, $n = 5$)

Fatty acid	Rainbow trout		Vendace		Pike	
	Raw	Cooked	Raw	Cooked	Raw	Cooked
14:0	63 ± 21	136 ± 85	23 ± 15	92 ± 43	3 ± 1	6 ± 1
16:0	303 ± 70	621 ± 265	113 ± 31	874 ± 394	76 ± 11	207 ± 23
18:0	73 ± 17	185 ± 62	33 ± 10	549 ± 308	19 ± 2	92 ± 12
20:0	—	—	—	37 ± 20	—	—
16:1*n*-(7+9)	119 ± 40	245 ± 146	42 ± 31	167 ± 83	9 ± 5	10 ± 1
18:1*n*-(7+9)	415 ± 140	1055 ± 436	93 ± 60	2085 ± 1176	51 ± 15	329 ± 58
20:1*n*-(9+11)	143 ± 51	277 ± 143	—	39 ± 19	—	—
22:1*n*-(9+11)	131 ± 47	248 ± 123	—	—	—	—
18:2*n*-6	98 ± 34	1070 ± 419	21 ± 15	5993 ± 3671	11 ± 4	951 ± 169
18:3*n*-3	26 ± 8	60 ± 29	26 ± 14	167 ± 76	3 ± 1	14 ± 1
18:4*n*-3	28 ± 10	57 ± 36	18 ± 11	72 ± 33	—	—
20:3*n*-3	4 ± 2	7 ± 4	—	—	—	—
20:3*n*-6	6 ± 1	9 ± 5	—	—	—	—
20:4*n*-3	33 ± 9	59 ± 31	12 ± 5	36 ± 12	—	—
20:4*n*-6	15 ± 3	21 ± 9	42 ± 11	110 ± 37	11 ± 1	14 ± 1
20:5*n*-3	143 ± 27	237 ± 111	69 ± 20	191 ± 56	31 ± 4	55 ± 6
22:4*n*-6	—	—	7 ± 2	21 ± 8	—	—
22:5*n*-3	69 ± 17	131 ± 47	22 ± 6	61 ± 20	10 ± 2	13 ± 2
22:5*n*-6	11 ± 2	11 ± 3	21 ± 5	49 ± 8	3 ± 1	2 ± 1
22:6*n*-3	511 ± 72	713 ± 255	186 ± 32	398 ± 64	192 ± 30	246 ± 28
Total	2191 ± 569	5142 ± 1940	728 ± 239	10941 ± 5844	419 ± 57	1939 ± 264
Moisture	73·3 ± 0·7	64·8 ± 0·8	77·6 ± 1·7	54·3 ± 8·2	78·9 ± 0·6	73·9 ± 1·1

slightly greater in MUFAs (9%) than in PUFAs (3%) and saturated FAs (2%). In vendace, the total FA concentration increased 159%. The greatest increase was found in 18-carbon PUFAs (over 300%) and in MUFAs (274%) and the smallest in DHA (93%). About 17% increase of FA content was found in pike. From the major FAs, the concentration of palmitic acid (16 : 0) increased most (29%) and that of stearic acid (18 : 0) increased least (6%).

Cooking in the microwave oven

The concentrations of all major FAs increased about 30% in rainbow trout (Table 3). The total FA content

Table 5. Fatty acid concentrations (mg/100 g) and moisture (%) in raw and rapeseed oil–fried fish flesh (mean ± SD, $n = 5$)

Fatty acid	Rainbow trout		Vendace		Pike	
	Raw	Cooked	Raw	Cooked	Raw	Cooked
14:0	247 ± 124	242 ± 118	42 ± 21	87 ± 32	2 ± 1	2 ± 0
16:0	1009 ± 447	994 ± 417	160 ± 44	543 ± 183	61 ± 3	159 ± 30
18:0	220 ± 95	218 ± 85	46 ± 13	181 ± 60	16 ± 1	86 ± 25
20:0	—	—	—	40 ± 16	—	11 ± 5
22:0	—	—	—	27 ± 12	—	11 ± 5
16:1*n*-(7+9)	393 ± 201	398 ± 194	74 ± 33	163 ± 60	7 ± 2	10 ± 1
18:1*n*-(7+9)	1274 ± 617	1581 ± 511	118 ± 43	4248 ± 1752	37 ± 6	1327 ± 357
20:1*n*-(9+11)	442 ± 221	451 ± 215	—	117 ± 48	—	39 ± 13
22:1*n*-(9+11)	442 ± 209	433 ± 206	—	69 ± 28	—	33 ± 11
18:2*n*-6	339 ± 181	451 ± 121	31 ± 11	1772 ± 744	6 ± 2	568 ± 160
18:3*n*-3	85 ± 41	132 ± 28	42 ± 19	782 ± 329	2 ± 1	233 ± 66
18:4*n*-3	102 ± 54	103 ± 50	31 ± 17	71 ± 33	—	—
20:3*n*-3	10 ± 6	11 ± 5	—	—	—	—
20:3*n*-6	12 ± 7	12 ± 5	—	—	—	—
20:4*n*-3	83 ± 39	83 ± 38	17 ± 6	33 ± 11	—	—
20:4*n*-6	32 ± 13	32 ± 12	57 ± 16	106 ± 28	11 ± 1	13 ± 2
20:5*n*-3	348 ± 148	350 ± 149	93 ± 29	181 ± 55	17 ± 1	19 ± 3
22:4*n*-6	—	—	11 ± 4	25 ± 8	—	—
22:5*n*-3	134 ± 58	135 ± 59	30 ± 8	56 ± 11	6 ± 1	11 ± 2
22:5*n*-6	16 ± 4	14 ± 4	27 ± 7	47 ± 10	4 ± 1	5 ± 1
22:6*n*-3	1078 ± 357	1036 ± 352	213 ± 47	392 ± 96	124 ± 10	143 ± 20
Total	6266 ± 2818	6675 ± 2552	992 ± 294	8940 ± 3460	293 ± 19	2670 ± 691
Moisture	70·4 ± 1·9	66·0 ± 2·8	77·6 ± 1·2	61·9 ± 6·9	79·9 ± 0·8	73·0 ± 1·7

of vendace increased 211%. Over 450% increases were found in the concentrations of MUFAs and 18-carbon PUFAs, while the concentration of DHA increased only 87%. In pike, the total content of FAs increased 50% without great differences between individual fatty acids.

Frying

The total concentration of FAs increased 119% in sunflower oil (SO)–fried rainbow trout (Table 4). The greatest increase took place in the content of linoleic acid (642%). Rainbow trout samples fried in rapeseed oil (RO) contained originally over 6 g FAs per 100 g flesh and only small increases of FAs derived from rapeseed oil (oleic, linoleic and linolenic acids) were observed (Table 5).

In vendace, total FA contents of less than 1 g per 100 g were increased almost to 11 g (SO) and 9 g (RO) per 100 g during frying. The amounts of oleic and linoleic acids in 100 g of flesh were about 2·1 g and 6·0 g after SO and 4·2 g and 1·8 g after RO frying, respectively. RO frying increased, also, the content of α-linolenic acid considerably (from 0·04 to 0·8 g per 100 g). The amounts of long chain PUFAs were almost doubled after RO and more than doubled after SO frying. The loss of moisture was much greater in fried than in baked or boiled vendace.

SO- and RO-derived FAs were found also in pike after frying. Their quantitative increases were, however, smaller than in vendace and the total FA contents were 1·9 and 2·7 g per 100 g after SO and RO frying, respectively.

DISCUSSION

The effects of cooking on FA concentrations of fish flesh were dependent upon the type of fish. The total FA contents were slightly increased without great differences between individual FAs in lean pike, if methods with no additional oil were used. This was mostly caused by the loss of moisture. In vendace, FA concentrations, however, increased considerably during cooking even when calculated on a dry weight basis. In addition, the concentrations of MUFAs and 18-carbon PUFAs were increased much more than other FAs. The only possible source of additional FAs is the depot fat under the skin of vendace. This fat consists mainly of neutral lipids, which contain far more MUFAs and short chain PUFAs than phospholipids (Kaitaranta, 1980). It is obvious that some deposit fat has melted and absorbed into the flesh with the assistance of the skin cover, which prevents the loss of lipids into the surroundings. With the exception of about a 3-fold increase of linoleic acid concentration in bluegill fillets, such an effect has not been found in baked sucker and bluegill (Mai *et al.*, 1978) or grouper and red snapper (Gall *et al.*, 1983). This may be explained by the removal of skin before cooking in those studies.

Increased MUFA and 18-carbon PUFA concentrations were found also in boiled rainbow trout but not in baked or microwave-cooked fish. This could be due to the originally lower FA content in the flesh of boiled samples, which seems to facilitate the absorption of fluidified deposit lipids. Baked and microwave-cooked samples originally contained more FAs than boiled ones, and no specific changes in FA profile were observed. This accords with the results obtained for lake trout (Mai *et al.*, 1978), Florida pompano (Gall *et al.*, 1983) and salmon (Dudek & Elkins, 1986), which have total lipid contents similar to rainbow trout. The total amount of FAs was slightly decreased (5%) in baked trout samples and increased (32%) in microwave-cooked rainbow trout samples, although they had about the same FA concentration before cooking. It is possible that the shorter cooking time in the microwave oven decreases the loss of fluidified lipids outside the flesh.

Size and lipid content of fish samples each influenced the effects of additional vegetable oils on FA concentrations. Small and lean vendace was the most fat-rich fish after frying, despite the fact that it was covered by the skin. Also, pike efficiently absorbed added oil, but the greater size and thickness of the samples prevented it becoming as oily as vendace. The effect of lipid content was clearly seen in fried rainbow trout. The samples fried in SO had originally much lower amounts of FAs (2·2 g/100 g) than RO-fried samples (6·3 g/100 g). Frying increased the amount of FAs more than twofold in SO-fried samples (5·1 g/100 g) while only a slight increase was found in RO-fried samples (6·7 g/100 g). It seems that the additional oil mainly determines the FA composition of small and lean fish and that its effect decreases with increasing lipid content of fish. These findings are in accordance with those obtained with pan and deep-fat frying of fish fillets with soybean oil (Mai *et al.*, 1978; Gall *et al.*, 1983). The absorption of additional oil stresses the importance of the frying oil selection, especially when lean fish is fried. The *n*-3 to *n*-6 ratio of flesh FAs was drastically changed when vendace was fried with SO (from 3·68 to 0·15). This shows that vegetable oils rich in *n*-6 FAs should be avoided in pan and deep-fat frying, if an increased *n*-3 FA intake at the expense of *n*-6 FAs is desired.

In general, long chain *n*-3 FAs were well retained in different cooking methods. Their concentrations in flesh increased in most cases (Fig. 1). Slight decreases (2–3%) were found only in baked and RO-fried rainbow trouts. The difference between SO- and RO-fried rainbow trouts may be caused by the lower lipid content of SO-fried samples before cooking. The flesh of these samples has probably absorbed, in addition to SO, some subcutaneous deposit fat. The greatest increases in long chain *n*-3 FA concentrations took place in baked and microwave-cooked vendace where about 70% increases were found, even if calculated on a dry weight basis. In SO- and RO-fried vendaces, this increase was mostly caused by the loss of moisture and about 10% increases took place when calculated on a dry weight basis. This suggests that the absorption of

cooking oils decreases the absorption of fish lipids located outside the flesh.

There are many variations in fish handling and cooking which alter the fate of lipid stores outside the flesh and thereby affect the amount of lipids lost or absorbed during cooking. In practice, all usual cooking methods can be used without significant loss of *n*-3 FAs. However, cooking methods without additional oil, especially without oils rich in *n*-6 FAs, are preferable.

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