Deep-Fat Frying Modifies High-Fat Fish Lipid Fraction

M. Candela, I. Astiasarán,* and J. Bello

Department of Food Science and Technology, University of Navarra, Irunlarrea s/n, Pamplona, 31008 Navarra, Spain

The lipid composition of three high-fat fishes (sardines, mackerel, and salmon) was analyzed to study the effect of deep-fat frying with sunflower oil and warmholding (65 °C, 3 h). Only sardines increased total fat content with cooking. Saturated fatty acids content decreased, especially in sardines and mackerel, mostly because of the palmitic acid reduction. Raw sardines and mackerel presented an important content of ω-3 polyunsaturated fatty acids (24.0 and 16.6 g/100 g of fat, respectively), but it decreased significantly during frying (6.6 and 5.4 g/100 g of fat, respectively). Salmon, despite having the lower amount of eicosapentaenoic acid and docosahexaenoic acid in raw samples, was the best source of these fatty acids after frying (1.7 g/100 g of food). The ratio of total ω-6 fatty acids to total ω-3 fatty acids increased with cooking from 0.12 to 1.07 in salmon, from 0.12 to 6.19 in mackerel, and from 0.07 to 5.98 in sardines. Cholesterol content was differently affected by frying: it increased in salmon and mackerel and decreased in sardine. Fatty acid and cholesterol were slightly affected by warmholding in all fishes.

Keywords: *High-fat fishes; frying; warmholding; lipids*

INTRODUCTION

In a previous paper (Candela et al., 1997) the modifications of the fatty acids and lipid fraction of three low-fat fishes (sole, codfish, and hake) as a consequence of deep-fat frying were analyzed. The ratio polyunsaturated/saturated (P/S) increased between 1.84 and 3.01 times, but at the same time the ratio of total ω-6 fatty acids to total ω-3 fatty acids increased between 21.75 and 26.85 times, giving rise to a negative effect on the benefits related to intake of eicosapentaenoic (EPA) and docosahexaenoic acid (DHA). Ågren and Hänninen (1993) established that vegetable oils rich in ω-6 PUFAs should be avoided in pan and deep-fat frying if an increase of ω-3 PUFA intake at the expense of ω-6 PUFAs is desired. Several studies with animals have shown that a high dietary fat intake, especially of ω-6 fatty acids, is related to an increased incidence of breast, prostate, and colon cancer (Carroll and Khor, 1971; Reddy, 1986), whereas diets high in ω-3 fatty acids (EPA and DHA) have beneficial effects against several types of malignant tumors (Cave, 1991; Karmali, 1989).

Most information about PUFA's content is available normally for raw fish. However, consumption of uncooked fish is unusual in Western society. One common method of cooking fish is deep-fat frying. Also, in catering it is usual to keep food at 65 °C for periods of 3 h.

Frying, contrary to popular belief, does not always result in an increase in the fat content (Makinson et al., 1987). Greenfield and Kosulwat (1991) in a comparative study confirmed that food kind and cooking procedures could influence fat variations. Furthermore, the fat content of raw fishes can influence fat exchanges and interactions between the culinary fat and that of the fish when frying (Sánchez-Muñiz et al., 1992).

* Author to whom correspondence should be addressed [telephone (948) 425600, ext. 6264; fax (948) 425649; e-mail iastiasa@unav.es].

The aim of this work was to study how deep-fat frying in sunflower oil and warmholding of three high-fat fishes affected their fatty acid composition and cholesterol, with special remarks concerning content of EPA and DHA and ω-6/ω-3 ratio changes.

MATERIALS AND METHODS

Materials and Preparation of Samples. Three different species of fish [salmon (*Salmon salar*), Spanish mackerel (*Scomberomorus commersoni*), and sardine (*Sardine pilchardus*)], traditionally considered as high-fat fishes, were studied. Fishes were purchased in the market. They were recently captured and stored with chopped ice. The study was carried out in four batches for each fish. Fish samples (corresponding to six helpings of ≈150 g each) were cooked by a catering industry firm following the usual process. They were introduced into an industrial deep fryer for 5 min with cooking oil (sunflower oil) at 180 °C. After draining, a quantity corresponding to three helpings was homogenized and immediately analyzed. The rest of the samples were introduced into a thermal unit used by the company for distribution. The internal temperature of food was 65 °C. After 3 h, the samples were homogenized and analyzed. Raw samples were analyzed in the same way. Each parameter was analyzed four times for each batch.

Analytical Procedures. Moisture content was calculated by drying (ISO, 1973a). Total fat was determined with an extraction technique using petroleum ether (ISO, 1973b). The method of Folch et al. (1957) was used for the extraction of fish fat. Fatty acid composition was determined by gas chromatography. BF_3/methanol was used for the preparation of fatty acid methyl esters (AOAC, 1990). An automatic Perkin-Elmer Autosystem model gas chromatograph fitted with an SP-2380 capillary column, 60 m × 0.25 mm, of fused silica (Supelco, Inc., Bellefonte, PA) and FID was used. The temperature of the injection port and detector was 250 °C, and the oven was programmed to increase from 170 to 200 °C at a rate of 2 °C/min. The carrier gas was hydrogen, 13 psig. The sample size was 0.5 μL. Peaks were identified by comparison of their retention times with those of standard mixtures (Sigma, St. Louis, MO, 99% purity specific for GC),

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Table 1. Moisture and Fat Content of Fishes[a]

	raw	cooked	warmheld
salmon			
moisture	69.3[a] ± 0.06	56.3[b] ± 1.09	51.2[c] ± 0.20
fat	12.0[a] ± 0.15	14.8[a] ± 0.30	15.9[a] ± 1.66
mackerel			
moisture	61.0[a] ± 0.10	64.6[b] ± 0.40	61.1[a] ± 0.02
fat	16.0[a] ± 0.20	7.25[b] ± 0.24	9.33[c] ± 0.08
sardines			
moisture	74.0[a] ± 0.48	56.7[b] ± 0.01	57.5[b] ± 0.19
fat	4.0[a] ± 0.20	13.3[b] ± 0.20	11.8[c] ± 0.20

[a] All values referred to g/100 g of food (mean ± standard derivations). Values in the same row bearing different letters are significantly different ($p \leq 0.05$).

and their areas were automatically integrated using nonadecanoic acid methyl ester (Sigma) as internal standard.

The cholesterol content was calculated according to the method of Kovacs et al. (1979) by gas chromatography. A Perkin-Elmer Sigma 300 + HS 6 with an SP-2250 colum, 2 m × 6 mm × 2 mm, packed with Supelcoport (Supelco, Inc., Bellefonte, PA) was used. The oven temperature was 260 °C. The temperature of the injection port and detector was 285 °C. Hydrogen, nitrogen, and air were carrier gases used. The sample size was 0.5 μL. Cholesterol standards (Sigma), with concentrations ranging from 0 to 1.5 mg/mL in chloroform, were used, and to each was added 1 mL of a cholestane (Sigma) solution in chloroform (2 mg/mL) as internal standard. After analysis, the cholesterol/cholestane area ratio was determined. With the weight of standard cholesterol and cholestane known, a plot of cholesterol/cholestane area ratio versus cholesterol/cholestane weight ratio was obtained. By referring to this standard curve, the amount of cholesterol of the unknown sample was calculated. A Perkin-Elmer Turbochrom program was used for quantification.

Statistical Analysis. Data analysis was carried out with one-way ANOVA and a Tuckey's posteriori test (Statgraphics 4.0). A significance level of $p \leq 0.05$ was used for all mean evaluation.

RESULTS AND DISCUSSION

Moisture and fat content of analyzed fishes are shown in Table 1. Raw salmon and mackerel showed much higher fat content than sardines. However, sardines were the only fish with a significant fat content increase following frying. This process did not significantly affect the fat content of salmon and produced a significant reduction in mackerel. Mai et al. (1978) found in a study on freshwater fish that in fish with high fat content few lipid changes were produced during frying. Different fish species would have different behaviors during the frying process, which should be taken into account to determine the total fat intake of a fish dish.

The effects of deep-fat frying on the individual fatty acids of the three fishes analyzed are presented in Tables 2−4. Saturated fatty acid (SFA) content decreased with frying process in all samples. Armstrong and Bergan (1992) pointed out that many cooking methods cause loss of lipid that can be due to drip, an effect that may be greater in fattier foods. They also said that this loss mainly involves neutral lipids and within this class it will be more pronounced for lower melting point molecules. Gall et al. (1983) found that frying with soybean oil produced a considerable decrease in the SFA content of all fishes studied. Palmitic acid was the major SFA in the raw fishes, but during the deep-fat frying process it decreased, producing the most important reduction in sardines and mackerel. This was also found by other authors (Sánchez-Muñiz et al., 1992; Gall et al., 1983). Oleic acid increased ~50% in sardines and mackerel and slightly in salmon, probably as a consequence of absorption from the cooking medium, sunflower oil, which is rich in this fatty acid. Despite this increase, the total content of monounsaturated fatty acids changed slightly with respect to raw fish because of the simultaneous loss of palmitoleic acid.

Different effects of frying on saturated and monounsaturated fatty acids could be explained by the kind of analyzed fish (initial fat content) as well as cooking oil selected. In a previous work an increase in saturated

Table 2. Fatty Acid Content of Salmon[a]

fatty acid (g/100 g of fat)	raw	fried	warmheld
myristic 14:0	4.62 ± 0.05[a]	3.74 ± 0.01[b]	3.93 ± 0.02[c]
palmitic 16:0	13.40 ± 0.05[a]	11.56 ± 0.03[b]	11.77 ± 0.03[c]
stearic 18:0	2.80 ± 0.01[a]	3.08 ± 0.03[b]	2.82 ± 0.02[a]
arachidic 20:0	0.53 ± 0.01[a]	0.51 ± 0.00[b]	0.46 ± 0.00[c]
palmitoleic cis-16:1ω-7	5.63 ± 0.06[a]	4.58 ± 0.02[b]	4.88 ± 0.02[c]
palmitelaidic trans-16:1ω-7	0.46 ± 0.00[a]	0.39 ± 0.01[a]	0.43 ± 0.03[a]
oleic cis-18:1ω-9	14.06 ± 0.03[a]	16.33 ± 0.02[b]	15.18 ± 0.03[c]
elaidic trans-18:1ω-9	0.49 ± 0.01[a]	0.43 ± 0.01[b]	0.42 ± 0.00[b]
erucic cis-22:1ω-9	1.49 ± 0.02[a]	1.24 ± 0.0[b]	1.32 ± 0.02[c]
brassidic trans-22:1ω-9	7.44 ± 0.11[a]	5.84 ± 0.13[b]	6.54 ± 0.06[c]
linoleic cis-18:2ω-6	1.85 ± 0.01[a]	14.21 ± 0.14[b]	9.02 ± 0.03[c]
linolelaidic trans-18:2ω-6			
linolenic cis-18:3ω-3	2.09 ± 0.02[a]	1.75 ± 0.01[b]	1.83 ± 0.01[c]
eicosapentaenoic cis-20:5ω-3	5.15 ± 0.11[a]	4.64 ± 0.16[a]	5.04 ± 0.17[a]
docosahexaenoic cis- 22:6ω-3	7.58 ± 0.23[a]	6.81 ± 0.37[a]	7.60 ± 0.47[a]
Σ saturated	21.35	18.89	18.98
Σ monounsaturated cis	21.18	22.15	21.38
Σ monounsaturated trans	8.39	6.66	7.39
Σ polyunsaturated cis	16.67	27.41	23.49
ω6/ω3	0.12	1.07	0.62

[a] All values referred to g/100 g of fat (mean ± standard derivations). Values in the same row bearing different letters are significantly different ($p \leq 0.05$).

Table 3. Fatty Acid Content of Mackerel[a]

fatty acid (g/100 g of fat)	raw	fried	warmheld
myristic 14:0	4.45 ± 0.04[a]	0.97 ± 0.00[b]	0.96 ± 0.01[b]
palmitic 16:0	13.57 ± 0.04[a]	7.71 ± 0.02[b]	7.97 ± 0.05[c]
stearic 18:0	2.60 ± 0.01[a]	4.09 ± 0.01[b]	4.34 ± 0.03[c]
arachidic 20:0			
palmitoleic cis-16:1ω-7	3.64 ± 0.04[a]	0.99 ± 0.00[b]	1.00 ± 0.01[b]
palmitelaidic trans-16:1ω-7	0.52 ± 0.05		
oleic cis-18:1ω-9	8.37 ± 0.03[a]	14.75 ± 0.20[b]	16.31 ± 0.09[c]
elaidic trans-18:1ω-9	0.83 ± 0.00		
erucic cis-22:1ω-9	1.25 ± 0.03[a]	0.67 ± 0.00[b]	0.70 ± 0.00[b]
brassidic trans-22:1ω-9	9.77 ± 0.25[a]	1.22 ± 0.03[b]	1.24 ± 0.02[b]
linoleic cis-18:2ω-6	2.26 ± 0.04[a]	40.21 ± 0.28[b]	42.19 ± 0.60[c]
linolelaidic trans-18:2ω-6		0.65 ± 0.01[b]	0.92 ± 0.03[c]
linolenic cis-18:3ω-3	1.94 ± 0.02[a]	1.08 ± 0.16[b]	0.99 ± 0.18[b]
eicosapentaenoic cis-20:5ω-3	4.62 ± 0.17[a]	1.30 ± 0.02[b]	1.14 ± 0.04[b]
docosahexaenoic cis-22:6ω-3	11.97 ± 0.99[a]	4.11 ± 0.11[b]	3.30 ± 0.23[b]
Σ saturated	21.23	13.35	13.91
Σ monounsaturated cis	13.26	16.41	18.01
Σ monounsaturated trans	11.12	1.22	1.24
Σ polyunsaturated cis	20.79	46.70	47.62
Σ polyunsaturated trans		0.65	0.92
ω6/ω3	0.12	6.19	7.70

[a] All values referred to g/100 g of fat (mean ± standard derivations). Values in the same row bearing different letters are significantly different ($p \leq 0.05$).

Table 4. Fatty Acid Content of Sardine[a]

fatty acid (g/100 g of fat)	raw	fried	warmheld
myristic 14:0	5.68 ± 0.05[a]	1.15 ± 0.01[b]	1.12 ± 0.00[b]
palmitic 16:0	17.80 ± 0.07[a]	8.46 ± 0.04[b]	8.29 ± 0.01[b]
stearic 18:0	3.09 ± 0.02[a]	4.10 ± 0.03[b]	3.93 ± 0.01[c]
arachidic 20:0	0.63 ± 0.03[a]	0.62 ± 0.00[a]	0.62 ± 0.01[a]
palmitoleic cis-16:1ω-7	5.89 ± 0.02[a]	1.16 ± 0.00[b]	1.16 ± 0.01[b]
palmitelaidic trans-16:1ω-7	0.91 ± 0.02		
oleic cis-18:1ω-9	7.38 ± 0.08[a]	15.43 ± 0.01[b]	14.93 ± 0.07[c]
elaidic trans-18:1ω-9	0.47 ± 0.02		
erucic cis-22:1ω-9	1.24 ± 0.01[a]	0.66 ± 0.01[b]	0.66 ± 0.00[b]
brassidic trans-22:1ω-9	3.83 ± 0.02		
linoleic cis-18:2ω-6	1.83 ± 0.02[a]	43.93 ± 0.64[b]	42.34 ± 0.11[c]
linolelaidic trans-18:2ω-6	0.75 ± 0.00[a]	0.64 ± 0.00[b]	0.65 ± 0.01[b]
linolenic cis-18:3ω-3	1.87 ± 0.01[a]	0.77 ± 0.00[b]	0.69 ± 0.02[b]
eicosapentaenoic cis-20:5ω-3	8.43 ± 0.11[a]	2.39 ± 0.15[b]	2.17 ± 0.01[b]
docosahexaenoic cis-22:6ω-3	15.53 ± 0.39[a]	4.19 ± 0.16[b]	4.12 ± 0.05[b]
Σ saturated	27.2	14.33	13.96
Σ monounsaturated cis	14.51	17.25	16.75
Σ monounsaturated trans	5.21		
Σ polyunsaturated cis	27.66	51.28	49.32
Σ polyunsaturated trans	0.75	0.64	0.65
ω6/ω3	0.07	5.98	6.06

[a] All values referred to g/100 g of fat (mean ± standard derivations). Values in the same row bearing different letters are significantly different ($p \leq 0.05$).

and monounsaturated fatty acids of low-fat fishes (codfish, hake, and sole) after frying was observed (Candela et al., 1997).

Maximets and Fedak (1993) showed that during cooking in sunflower oil trans fatty acids were formed. These acids appeared in significant amount in the three fishes, specially monounsaturated trans acids. However, in all cases frying reduced significantly these trans monounsaturated fatty acids, the intake of which would be 0.98, 0.09, and 0 g/100 g of food for salmon, mackerel, and sardines, respectively.

The modifications observed in the content of EPA and DHA were especially important. Raw sardines and mackerel showed a great amount of these ω-3 PUFAs: 24.0 and 16.6 g/100 g of fat, respectively. Frying produced an important reduction of these values to 6.6 and 5.4 g/100 g of fat, respectively. Other authors also found a negative effect on these fatty acids in sardines (Ohgaki et al., 1994; Sánchez-Muñiz et al., 1992). However, Sebedio et al. (1993) affirmed that the longer chain ω-3 polyunsaturated fatty acid content of mackerel was not affected by deep-fat frying and geometrical fatty acid isomers of long-chain highly polyunsaturated fatty acids were formed during this process.

No significant changes were found in EPA and DHA contents in salmon. The overall amounts of these ω-3 fatty acids decreased only from 12.7 g/100 g of fat in raw samples to 11.5 g/100 g of fat in fried ones.

The different behaviors observed in the analyzed fishes could indicate that the changes in EPA and DHA were related to the initial amount in raw fish and therefore to species. This explanation is supported by Shozen et al. (1995), who affirmed that in marine fish products rich in EPA, the decrease in the level of PUFAs after grilling was fairly large, whereas in products with lower levels of EPA, the decrease in the level of PUFAs was relatively small. This fact was also observed when low-fat fishes were analyzed (Candela et al., 1997). In those samples the preparation included a coating with wheat flour and egg prior to deep-fat frying, which could also have an influence in the minor modification observed. If data were referred to the amount supplied by 100 g of food to know the real intake of the different fatty acids, raw salmon and mackerel appeared to be the main source of ω-3 PUFAs. However, frying reduced significantly the content of these fatty acids in mackerel. The intake of EPA and DHA from these fried fishes would be 1.7 g/100 g of food for salmon, 0.39 g/100 g of food for mackerel, and 0.88 g/100 g of food for sardines.

Table 5. Cholesterol Content[a]

	raw	fried	warmheld
salmon	374.25 ± 12.43[a]	476.28 ± 59.19[b]	409.11 ± 13.08[b]
mackerel	290.06 ± 6.52[a]	546.90 ± 20.32[b]	492.17 ± 7.37[c]
sardine	1661.25 ± 1.05[a]	607.29 ± 7.37[b]	718.22 ± 37.09[c]

[a] All values referred to mg/100 g of fat (mean ± standard deviations). Values in the same row bearing different letters are significantly different ($p \leq 0.05$).

The ratio of ω-6/ω-3 increased 8.92-fold following the cooking of salmon (from 0.12 to 1.07), 51.6-fold in mackerel (from 0.12 to 6.19), and 85.4-fold in sardines (from 0.07 to 5.98). Fried salmon presented the best dietary ratio ω-6/ω-3 because of the great stability of EPA and DHA and the small absorption of linoleic acid during frying.

In general, seafood is not a major source of dietary cholesterol. Deep-fat frying did affect the cholesterol content (Table 5), producing a significant increase in salmon and mackerel and a decrease in sardine. Mai et al. (1978) explained this decrease in some fish species by elution of the cholesterol in the frying oil. Sánchez-Muñiz et al. (1992) showed that cholesterol content decreased in sardines mainly due to absorption of culinary fat.

Cholesterol intake for cooked fishes would be 70.49 mg/100 g of food for salmon, 39.65 mg/100 g of food for mackerel, and 80.77 mg/100 g of food for sardines.

The modifications produced by warmholding were not so relevant as those produced by cooking. This fact was also observed in low-fat fishes. There was a decrease in linoleic content of salmon that enhanced the ω-6/ω-3 ratio. In sardines and mackerel this ratio increased slightly. No changes were found in the cholesterol content of salmon. Cholesterol content decreased for mackerel and increased for sardines.

In conclusion, deep-fat frying with sunflower oil decreased the content in saturated fatty acids and fatty acids with trans configurations. Salmon, despite having the lower amount of EPA and DHA in raw samples, was the best source of these fatty acids, probably because of their relative stability during the frying process. Sardines and mackerel submitted to deep-fat frying would have reduced beneficial effects arising from their lipid fraction.

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