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Effects of Cooking by Different Methods on the Polyunsaturated Fatty Acids in Six Fish Species

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Abstract. The effect of cooking on the fatty acid content and the stability of n-3 fatty acids in fish flesh were studied. The cooking methods used were baking, frying with palm oil, steaming, boiling and microwave oven. Six fish species (kanad, Shoar, Hamor, Bory, Morgan, and Bolty) were studied. The content of n-3 PUFA in fish flesh were more than 23% of total lipids except Bolty which contained only 16% of total lipids. The n-3 PUFA content in flesh decreased in most species due to frying. The n-3/n-6 ratio was approximately one for morgan, shoar and bolty while for other was higher. Based on these data, all cooking methods can be used without significant loss of n-3/n-6 PUFA ratio especially if the cooking oil does not interfere with the biological effects on n-3 fatty acids.

Introduction

The effects of n-3 polyunsaturated fatty acid (PUFA) on lipid metabolism have been extensively studied in the last decade [1, p. 128; 2, 3, p. 167; 4, p. 268]. These fatty acids (FA's) have been shown to modify n-6 (PUFA) metabolism [5]. It has also been suggested that an increased daily intake of n-3 PUFA to 0.5-1 g/day would reduce risk of cardiovascular death [6-7]. Increasing the intake of PUFA precursor, α-linolenic acid, will lead to increased n-3 PUFA in plasma [8] and show anti-aggregatory effects on platelets [9-10]. Dietary trials aimed at reducing the risk of cardiovascular diseases have emphasized the importance of ingesting marine oil and fish products that are rich in n-3 PUFA and poor in n-6 PUFA [11-12]. The beneficial effects have been attributed to an increased ratio of n-3 to n-6 PUFA in blood lipid and cell membrane lipids.

Fish and other aquatic food stuffs are the major source of long chain n-3 fatty acid in human nutrition. The fatty acid composition of raw fish has been widely studied by Ackman [13]. However, the number of reports concerning the effects of cooking on the stability of n-3 FA's is limited [14-16].

The aim of this study was to examine how different cooking methods affect FA content of fish. Six important species in Saudi market with a different size and fat content were selected for this study.

Materials and Methods

Sampling

The study was conducted during the year 1996. Six fish species which are most commonly consumed in Saudi Arabia were obtained from one of the largest fish markets in Riyadh City. The fish species obtained were Kanad (*Scomberomrus commerson*), Shoar (*Lethrinus minatus*), Hamor (*Epinephelus microdon*), Bory or Araby (*Valamugil seheli*), Morgan or Anteg (*Pristipomoides typus*) and Bolty (*Tilapia mozambique*). The fish, except bolty species, were all caught from the Arabian Gulf east of Saudi Arabia, and were landed several hours after the catch. On board, they were kept covered with ice and were subsequently shipped in a refrigerated truck to the commercial fish store. On arrival they were immediately transported under ice to the laboratory for sample preparation and analysis. Bolty is fresh water fish that is grown in Fish farms in Saudi Arabia.

Upon arrival, a sample from each fish species was washed with cold water and filleted then it was cut up to pieces and was then divided into six lots. These were: one for control (raw fish) and the others for baking, frying, steaming, boiling, and microwave cooking.

For the first lot (raw fish), the skin was removed and the edible portions (muscles) of the fish were handseparated and then ground through a 0.31 cm. plate four times to obtain a homogenous sample. For the remaining lots, the skin of the fish were also removed after the cooking process. For each of the above six cases (raw, baked, fried, steamed, boiled and microwaved), three composite samples were prepared from each species where the edible portion from three fish of the same species were ground to a composite sample. The samples were wrapped in plastic films, overwrapped with aluminium foil, and stored in the freezer at -20°C until it was subjected for analysis.

Cooking methods

Frying: Fish were placed in a frier rack AEG Electrical fried Type EWK 0037 Model FT 102 and cooked using palm oil having a fatty acid composition of about 45%, palmitic acid (16:0), 37% oleic acid (18:1), and 11% linoleic acid (18:2), and heated to 170°C for 4 minutes.

Baking: Fish were cooked uncovered in a dry heat oven model NMK, Barbecue King Ltd., Reading, U.K. (130°C for 25 minutes).

Microwave cooking: Fish were cooked uncovered for 2 min. in Tappan microwave oven model 65-4787-10/01174. operating at 2450 MHz.

Boiling: The fish were placed in heat resistant polyester (ICSIS) bags in boiling water for 6-10 min. and then immersed directly in cold water to prevent over cooking.

Steaming: Fish were cooked in an open autoclave for 10 min.

Lipid and moisture:

Lipid was extracted according to the method of Folch et al. [17] using chloroform-methanol (2:1 v/v). Total lipid content was obtained before and after cooking of all and was determined gravimetrically.

Moisture was determined by drying weighed samples in vacuum oven at 70°C to a constant weight.

Fatty acid analyses

Fatty acid methyl esters (FAME) were prepared as described by Metcalf *et al.*[18]. Aliquotes of lipid extract were saponified with methanolic KOH(0.5N) solution by refluxing for 15 min. at 90°C. After addition of 4 ml boron triflouride methanol reagent (20% BF3 in methanol), the sample was boiled for another 2 min. FAME were extracted twice with hexane and analysed by gas liquid chromatography GC 17A equipped CR6A integrator (Shimadzu Co. Japan) and a capillary column, Supelco wax 10, 30m × 0.32 id, 0.50 um film thickness (Supelco, Bellefone, PA). The oven temperature was programmed from 110 to 185°C at 2°C/min., and then increased to 220°C at a rate of 4°C/min. with a final hold time 5 min. Injector port and flame ionization detector temperature were 250°C and 260°C, respectively. Helium was used as a carrier gas at inlet pressure 1.2 kg/cm^2. Six standard mixtures of 22 pure FAME (Supelco and Sigma Co.) were used to confirm the identification. Fatty acid methyl esters whose relative retention time did not directly correspond with that of available standard FAME were named as "others". Standards were routinely chromatographed to establish retention times in order to determine the response factor for the individual fatty acid. All FA's esters were run in duplicate. Pentadecanoate was used as an internal standard.

Statistical anlysis

Data were analysed by analysis of variance (ANOVA) using statistical analysis system programm SAS [19]. Differences among the means were determined for significance using Duncan's multiple range test [20, p. 63].

Results and Discussion

The effect of different cooking methods on lipid content, fatty acid composition and moisture content in fish fillets are summarized in (Tables 1 to 6). The lipid content of fillets on fresh weight basis from the six species ranged from 2.5% in morgan to 8.6% in kanad. The lipid content and the composition of fatty acid in fish samples may

be related to factors such as size, habitat, physical and nutritional status [21-23]. The changes observed in the amount of total lipid as the result of cooking fillets (not fried) appears to be directly related to the original lipid content of the raw fillets. The lipid content of baked, steamed and microwave cooked samples of all the species increased slightly in comparison with the lipid content of raw fillet. During cooking, moisture was decreased, but there was no apparent loss of lipids when compared to raw fillets as shown in (Tables 1 to 6).

Table 1. Lipid , moisture (%), and fatty acid composition of lipid (% total lipid) in kanad fish, as affected by cooking method

Fatty acid	Raw	Baking	Frying	Steaming	Boiling	Microwave
14:0	5.8^{a}±0.8	6.0^{a}±1.7	5.1^{a}±0.2	5.8^{a}±1.8	6.9^{a}±0.4	7.0^{a}±0.5
16:0	18.2^{a}±0.8	17.8^{a}±5.0	21.1^{a}±1.0	17.1^{a}±5.4	20.3^{a}±1.7	19.2^{a} ±1.6
18:0	4.8^{a}±0.7	4.6^{a}±1.3	4.7^{a}±0.2	4.6^{a}±1.5	5.7^{a}±0.2	5.2^{a}±0.5
20:0	1.1^{abc}±0.7	1.8^{ab}±0.5	2.0^{a}±0.1	0.7^{c}±0.3	1.0^{bc}±0.8	0.6^{c}±0.1
TOTAL	29.9±3.0	30.2±8.5	32.9±1.5	28.2±9.0	33.9±3.1	32.0±2.7
16:1	8.0^{a}±1.1	8.2^{a}±2.5	7.3^{a}±0.3	7.7^{a}±3.0	9.2^{a}±0.8	9.3^{a}±0.7
18:1	12.0^{b}±1.3	12.3^{b}±3.4	15.4^{a}±0.9	11.3^{b}±2.9	13.9^{b}±0.4	13.1^{b}±1.1
20:1	4.4^{a}±1.8	5.2^{a}±0.2	2.3^{b}±0.1	4.0^{ab}±1.2	4.0^{ab}±0.8	3.7^{ab}±0.9
22:1	4.1^{a}±0.3	4.0^{a}±2.7	3.0^{a}±0.1	4.6^{a}±2.3	4.0^{a}±0.1	3.1^{a}±0.7
TOTAL	28.5±4.5	29.7±8.5	28.0±1.4	27.6±9.4	31.1±2.1	29.2±3.4
18:2 n-6	1.9^{b}±0.2	2.1^{b}±0.4	3.2^{a}±0.1	2.0^{b}±0.3	2.3^{b}±1.0	1.8^{b}±0.2
18:3 n-3	0.8^{a}±0.5	1.4^{a}±0.2	0.9^{a}±0.1	0.9^{a}±0.8	0.8^{a}±0.6	0.7^{a}±0.3
20:2 n-6						
20:3 n-3						
20:4 n-6	3.3^{a}±1.0	2.8^{a}±0.2	3.1^{a}±0.1	2.9^{a}±1.7	2.6^{a}±1.4	2.0^{a}±0.3
20:5 n-3	14.1^{a}±1.5	13.9^{a}±4.3	12.4^{a}±0.6	15.3^{a}±2.6	13.0^{a}±0.2	13.9^{a}±1.0
22:4 n-6	2.6^{a}±0.1	1.7^{a}±1.5	1.8^{a}±0.1	3.2^{a}±2.0	1.1^{a}±0.2	2.0^{a}±1.0
22:5 n-3	5.0^{a}±0.1	4.3^{a}±2.4	3.9^{a}±0.1	5.3^{a}±1.6	3.5^{a}±0.2	4.9^{a}±1.0
22:6 n-3	10.3^{a}±0.1	10.5^{a}±0.4	10.3^{a}±0.4	10.7^{a}±1.3	10.2^{a}±1.5	11.4^{a}±1.5
TOTAL	38.0±3.5	36.7±9.4	35.6±1.1	40.3±10.3	33.5±5.1	36.7±6.3
OTHERS	3.6^{a}±0.7	3.4^{a}±3.3	3.5^{a}±2.4	3.8^{a}±2.4	1.2^{a}±0.4	2.0^{a}±1.0
n-3	30.2	30.1	27.5	32.2	27.5	30.9
n-6	7.8	6.6	8.1	8.1	6.0	5.8
n3/n6	3.9	4.6	4.6	4.0	4.6	5.3
Lipid, %	8.6	9.1	9.0	9.3	8.9	10.1
Moisture (%)	74.39	69.3	57.0	72.0	70.4	68.3

Means in the same row, followed by different superscripts letters are significantly different ($p<0.05$).
(Means ± standard deviation, n=3).

There was no apparent change of lipids content of kanad even after frying. Other fish morgan, shaor, bolty and bory with respect to raw lipid content of 2.5%, 3.9%, 4.4% 3.5% , have absorbed as much as twice their lipid content after frying. However, lipid in hamor fillets (raw 5.1%) has shown little increase of lipid content after frying.

This indicated that gain or loss of lipids from fish is closely related to the lipid content of raw fillets. As the amount of lipid in raw fillet increased, the oil absorbed from the cooking medium decreased. A similar study also showed that fish fillets containing lower amounts of lipid tended to absorb more oil during cooking [14, 15].

Table 2. Lipid, moisture (%) and fatty acid composition of lipids (% total lipid) in shaor fish as affected by cooking method

Fatty acid	Raw	Baking	Frying	Steaming	Boiling	Microwave
14:0	$0.7^{b}\pm0.5$	$0.9^{b}\pm0.2$	$0.9^{b}\pm0.3$	$2.3^{a}\pm0.2$	$0.8^{b}\pm0.8$	$1.4^{b}\pm0.7$
16:0	$12.3^{bc}\pm8.5$	$12.3^{c}\pm3.5$	$23.1^{a}\pm6.8$	$15.8^{ab}\pm1.9$	$6.3^{c}\pm2.3$	$8.8^{c}\pm2.3$
18:0	$4.0^{bc}\pm1.0$	$6.1^{ab}\pm2.2$	$3.1^{c}\pm1.0$	$7.3^{a}\pm0.3$	$3.4^{bc}\pm0.9$	$4.7^{bc}\pm1.7$
20:0	$2.6^{b}\pm0.9$	$1.0^{b}\pm1.2$	$2.0^{b}\pm1.4$	$1.4^{b}\pm0.8$	$2.7^{b}\pm3.2$	$2.6^{a}\pm1.4$
TOTAL	19.6±10.9	20.3±7.1	29.1±9.5	26.8±3.2	13.2±7.2	17.5±6.1
16:1	$2.0^{c}\pm1.0$	$2.3^{c}\pm0.8$	$1.3^{a}\pm0.5$	$6.3^{c}\pm0.2$	$2.2^{c}\pm1.0$	$2.6^{b}\pm1.2$
18:1	$8.1^{c}\pm0.6$	$10.2^{bc}\pm3.6$	$26.2^{a}\pm7.5$	$15.7^{b}\pm1.2$	$6.9^{c}\pm1.1$	$10.6^{bc}\pm3.0$
20:1	$3.6^{a}\pm1.8$	$2.4^{a}\pm1.9$	$3.0^{a}\pm2.0$	$3.4^{a}\pm1.9$	$5.0^{a}\pm1.9$	$4.4^{a}\pm2.7$
22:1						
TOTAL	13.7±3.4	14.9±6.3	30.5±10.0	25.4±3.3	14.1±4.0	17.6±6.9
18:2 n-6	$2.0^{b}\pm0.9$	$2.2^{b}\pm2.4$	$6.4^{a}\pm1.8$	$2.9^{b}\pm0.9$	$1.2^{b}\pm0.5$	$2.0^{b}\pm1.1$
18:3 n-3	$1.2^{a}\pm0.1$	$1.2^{a}\pm1.1$	$1.3^{a}\pm0.8$	$1.3^{a}\pm0.9$	$1.9^{a}\pm0.9$	$2.2^{a}\pm1.9$
20:2 n-6	$2.6^{a}\pm0.6$	$2.0^{a}\pm0.6$	$1.3^{a}\pm1.2$	$0.8^{a}\pm1.7$	-	$2.7^{a}\pm0.3$
20:3 n-3						
20:4 n-6	$13.7^{a}\pm2.6$	$10.4^{ab}\pm2.2$	$5.0^{c}\pm2.2$	$6.0^{c}\pm0.8$	$13.2^{a}\pm1.6$	$9.8^{b}\pm0.9$
20:5 n-3	$14.2^{ab}\pm2.0$	$16.3^{ab}\pm5.5$	$10.0^{b}\pm6.2$	$8.0^{b}\pm2.6$	$19.5^{a}\pm4.4$	$14.8^{b}\pm3.5$
22:4 n-6	$6.4^{a}\pm1.6$	$5.6^{ab}\pm2.7$	$2.6^{b}\pm0.4$	$4.8^{b}\pm1.3$	$6.7^{a}\pm0.9$	$6.9^{ab}\pm1.9$
22:5 n-3	$4.3^{ab}\pm0.7$	$5.7^{ab}\pm2.2$	$2.8^{b}\pm1.0$	$5.2^{ab}\pm1.4$	$6.3^{a}\pm1.6$	$4.3^{ab}\pm2.0$
22:6 n-3	$14.0^{ab}\pm2.2$	$17.3^{a}\pm3.7$	$6.7^{c}\pm2.1$	$12.8^{b}\pm1.1$	$13.8^{ab}\pm3.0$	$16.1^{ab}\pm2.0$
TOTAL	58.4±10.7	60.7±20.4	36.1±15.7	41.8±10.7	62.6±12.9	58.8±13.6
OTHERS	$8.3^{ab}\pm0.1$	$4.1^{bc}\pm3.7$	$4.3^{c}\pm2.1$	$5.9^{c}\pm2.1$	$10.0^{a}\pm0.9$	$6.0^{abc}\pm2.5$
n-3	33.9	40.5	20.8	26.8	41.5	39.0
n-6	24.7	24.7	15.3	14.5	21.1	21.4
n3/n6	1.4	1.7	1.3	1.8	2.0	1.8
Lipid%	3.9	2.6	8.0	2.7	2.4	3.6
Moisture (%)	79.23	70.6	56.3	75.8	75.4	72.7

Means in same row, followed by different superscripts letters are significantly different ($p< 0.05$).
(Means ± standard deviation, n=3).

The fatty acid composition of all six species was dominated by the n-3 PUFA, particularly docosahexaenoic acid (DHA; C22:6 n-3). However, eicosapentaenoic acid (C20:5 n-3) was more than 10% in all species except in hamor and bolty, it was 5% of the total fatty acids. Docosapentaenoic acid (DPA C22:5 n-3) and ∝-lenolenic acid (C18:3 n-3) were also identified in all samples but their proportions were generally less than 5 and 2% of the total fatty acid, respectively. The proportion of DHA and DPA

was almost the same in bolty and bory. Eicosatrienoic acid, C20:3 n-3, level in hamor and bolty was found to be 2% of total fatty acids.

The n-6 series PUFA were also present in all the six species with hamor and kanad species having less than 10% of total lipids, whereas morgan showed the highest percentage of n-6 series PUFA, 26.5% of total lipids, followed by shaor (24.7%), bolty (19.3%) and bory (13.1%). The major n-6 series PUFA in all six samples was arachidonic aicd (C20:4 n-6). Morgan and shaor contained more than 10% of C20:4 n-6 as compared to the other four species. The level of C20:4 n-6 in these four species was less than 4%. Linoleic acid (C18:2 n-6) was found almost at a level ranging from 2 to 3% in all species except in bolty where it constituted about 10% of the total fatty acids.

Table 3. Lipid, moisture (%), and fatty acid composition of lipids (% total lipids) in hamor fish, as affected by cooking method

Fatty acid	Raw	Baking	Frying	Steaming	Boiling	Microwave
14:0	$2.4^{ab}\pm0.2$	$2.7^{a}\pm0.3$	$2.3^{b}\pm0.3$	$2.3^{b}\pm0.6$	$2.6^{ab}\pm0.1$	$2.5^{ab}\pm0.1$
16:0	$21.3^{bc}\pm1.0$	$23.8^{b}\pm3.0$	$29.5^{a}\pm0.5$	$18.2^{c}\pm5.0$	$19.8^{bc}\pm0.3$	$19.4^{bc}\pm0.3$
18:0	$6.4^{a}\pm0.2$	$6.7^{a}\pm0.7$	$5.7^{a}\pm3.8$	$5.9^{a}\pm1.7$	$5.7^{a}\pm0.1$	$5.9^{a}\pm0.3$
20:0	$1.2^{ab}\pm0.6$	$0.6^{c}\pm0.2$	–	$1.2^{a}\pm0.9$	$0.4^{bc}\pm0.1$	$0.7^{abc}\pm0.1$
TOTAL	31.3±2.0	33.8±4.2	37.5±4.7	27.6±8.2	28.5±0.6	28.5±0.8
16:1	$7.3^{ab}\pm0.1$	$7.7^{a}\pm1.3$	$4.9^{c}\pm0.8$	$5.8^{bc}\pm1.6$	$6.2^{abc}\pm0.1$	$6.1^{abc}\pm0.2$
18:1	$15.8^{b}\pm0.3$	$15.7^{b}\pm1.5$	$26.3^{a}\pm3.7$	$14.3^{b}\pm3.9$	$14.0^{b}\pm0.2$	$13.7^{b}\pm0.5$
20:1	$4.3^{a}\pm1.2$	$2.1^{b}\pm0.3$	$1.7^{b}\pm1.8$	$5.0^{a}\pm1.6$	$3.1^{ab}\pm0.1$	$3.0^{ab}\pm0.2$
22:1	$1.7^{a}\pm0.6$	$2.4^{a}\pm0.8$	$1.7^{a}\pm2.3$	$2.6^{a}\pm2.1$	$4.3^{a}\pm2.5$	$2.6^{a}\pm0.6$
TOTAL	29.1±2.2	27.9±3.9	34.6±8.6	27.7±9.2	27.6±2.9	25.4±1.5
18:2 n-6	$3.0^{b}\pm1.0$	$1.6^{c}\pm0.3$	$6.0^{a}\pm0.7$	$2.9^{b}\pm1.1$	$1.8^{bc}\pm0.1$	$1.8^{bc}\pm0.1$
18:3 n-3	$2.0^{ab}\pm1.0$	$0.4^{c}\pm0.3$	–	$2.2^{a}\pm0.9$	$0.9^{bc}\pm0.1$	$0.8^{bc}\pm0.3$
20:2 n-6	$2.0^{ab}\pm0.2$	$0.5^{c}\pm0.3$	$0.6^{c}\pm0.3$	$2.7^{a}\pm1.0$	$1.6^{b}\pm0.2$	$1.7^{b}\pm0.1$
20:3 n-3	$2.0^{ab}\pm0.3$	$0.7^{cd}\pm0.3$	$0.1^{d}\pm0.1$	$2.3^{a}\pm0.8$	$1.4^{bc}\pm0.2$	$1.5^{bc}\pm0.4$
20:4 n-6	$3.0^{ab}\pm0.5$	$3.3^{a}\pm1.3$	$1.7^{b}\pm0.7$	$4.0^{a}\pm1.0$	$3.4^{a}\pm0.1$	$3.6^{a}\pm0.3$
20:5 n-3	$4.6^{ab}\pm0.2$	$7.2^{a}\pm1.0$	$4.3^{ab}\pm3.8$	$3.3^{ab}\pm0.5$	$6.0^{ab}\pm2.4$	$4.9^{ab}\pm0.4$
22:4 n-6	$1.7^{ab}\pm0.8$	$2.7^{ab}\pm1.1$	$1.3^{b}\pm0.2$	$3.1^{ab}\pm2.6$	$3.5^{ab}\pm0.4$	$4.6^{a}\pm0.9$
22:5 n-3	$5.3^{ab}\pm1.1$	$6.1^{ab}\pm0.8$	$3.9^{b}\pm1.0$	$6.3^{a}\pm2.6$	$7.2^{a}\pm0.4$	$7.5^{a}\pm0.5$
22:6 n-3	$11.7^{ab}\pm1.9$	$12.6^{a}\pm3.0$	$8.3^{b}\pm0.8$	$14.0^{a}\pm3.9$	$13.3^{a}\pm0.6$	$14.9^{a}\pm1.1$
TOTAL	35.4±7.0	35.1±8.4	26.2±7.6	40.8±11.8	39.1±4.5	40.9±4.1
OTHERS	$4.1^{a}\pm2.1$	$3.2^{a}\pm1.1$	$1.7^{a}\pm0.5$	$3.9^{a}\pm3.1$	$4.7^{a}\pm0.6$	$4.7^{a}\pm0.6$
n-3	25.2	27.0	16.8	27.9	28.8	29.7
n-6	9.7	8.1	9.6	12.7	10.3	11.3
n3/n6	2.5	3.3	1.8	2.2	2.8	2.6
Lipid %	5.1	5.8	6.4	4.9	4.2	6.1
Moisture (%)	78.5	70.4	67.3	75.9	76.4	74.7

Means in same row, followed by different superscripts letters are significantly different ($p<0.05$).

(Means ± standard deviation, n=3) .

Table 4. Lipid, moisture (%), and fatty acid composition of lipids (% total lipid) in bory fish as affected by cooking method

Fatty acid	Raw	Baking	Frying	Steaming	Boiling	Microwave
14:0	$4.0^{abc}\pm0.1$	$5.3^{a}\pm0.2$	$2.5^{d}\pm0.2$	$3.1^{cd}\pm1.0$	$3.9^{c}\pm1.0$	$4.9^{ab}\pm0.5$
16:0	$20.7^{b}\pm0.2$	$22.2^{b}\pm1.0$	$30.4^{a}\pm2.0$	$14.0^{c}\pm4.6$	$21.2^{b}\pm1.5$	$21.1^{b}\pm1.7$
18:0	$3.3^{a}\pm0.1$	$3.8^{a}\pm0.3$	$3.7^{a}\pm0.2$	$2.8^{a}\pm0.5$	$3.4^{a}\pm1.0$	$3.8^{a}\pm0.4$
20:0	$1.9^{ab}\pm0.2$	$1.2^{ab}\pm0.8$	$0.7^{ab}\pm0.8$	$1.0^{ab}\pm1.0$	$2.3^{a}\pm1.9$	$2.0^{ab}\pm0.1$
TOTAL	29.9±0.6	32.5±2.3	37.3±3.2	20.9±7.1	30.8±5.4	31.8±2.7
16:1	$13.2^{a}\pm0.2$	$15.7^{a}\pm1.0$	$5.8^{c}\pm0.4$	$9.7^{b}\pm3.1$	$13.8^{a}\pm1.2$	$14.8^{a}\pm1.5$
18:1	$9.9^{bc}\pm0.1$	$10.6^{bc}\pm0.9$	$30.1^{a}\pm2.2$	$7.3^{c}\pm1.8$	$10.0^{abc}\pm3.3$	$12.0^{b}\pm0.7$
20:!	$4.0^{ab}\pm0.6$	$3.0^{ab}\pm1.8$	$1.3^{ab}\pm0.4$	$3.3^{ab}\pm1.9$	$4.7^{a}\pm2.1$	$3.0^{ab}\pm1.4$
22:1	$3.1^{a}\pm0.1$	$2.1^{a}\pm0.4$	$1.8^{a}\pm1.2$	$3.2^{a}\pm0.3$	$2.3^{a}\pm1.0$	$2.1^{a}\pm0.5$
TOTAL	30.2±1.0	31.4±4.1	39.0±4.2	23.5±7.1	30.8±7.6	31.9±4.1
18:2 n-6	$2.5^{b}\pm0.1$	$2.6^{b}\pm1.1$	$7.3^{a}\pm1.0$	$1.8^{b}\pm1.0$	$2.8^{b}\pm2.0$	$2.2^{b}\pm0.8$
18:3 n-3	$1.0^{a}\pm0.1$	$1.1^{a}\pm1.1$	$0.4^{a}\pm0.1$	$1.0^{a}\pm1.0$	$1.6^{a}\pm1.1$	$1.1^{a}\pm0.5$
20:2 n-6	$2.0^{a}\pm0.2$	$1.1^{ab}\pm1.0$	$0.1^{b}\pm0.1$	$2.0^{a}\pm1.0$	$2.0^{a}\pm0.4$	$1.6^{ab}\pm0.6$
20:3 n-3						
20:4 n-6	$5.4^{abc}\pm0.1$	$3.2^{cd}\pm0.5$	$1.4^{d}\pm0.$	$7.4^{a}\pm2.7$	$6.0^{ab}\pm1.2$	$4.0^{bc}\pm0.2$
20:5 n-3	$11.3^{b}\pm0.1$	$10.4^{b}\pm1.8$	$6.3^{b}\pm3.3$	$18.9^{a}\pm3.7$	$11.7^{b}\pm3.7$	$10.6^{b}\pm1.3$
22:4 n-6	$3.2^{ab}\pm0.1$	$2.0^{b}\pm1.8$	$1.6^{ab}\pm0.7$	$6.3^{a}\pm3.5$	$2.0^{b}\pm2.0$	$2.2^{b}\pm1.1$
22:5 n-3	$6.3^{a}\pm0.1$	$7.7^{a}\pm3.3$	$2.3^{b}\pm0.2$	$6.7^{a}\pm0.7$	$4.9^{ab}\pm2.9$	$5.6^{ab}\pm1.1$
22:6 n-3	$5.0^{ab}\pm0.1$	$5.6^{a}\pm2.2$	$2.3^{b}\pm0.3$	$5.2^{ab}\pm1.4$	$4.4^{ab}\pm1.6$	$6.0^{a}\pm1.6$
TOTAL	36.7±0.9	33.7±12.8	21.7±7.9	41.3±14.0	35.4±14.9	33.3±7.2
OTHERS	$3.2^{ab}\pm0.1$	$2.4^{b}\pm0.2$	$2.0^{b}\pm0.6$	$6.3^{a}\pm1.3$	$3.0^{ab}\pm3.6$	$3.0^{ab}\pm1.7$
n-3	23.6	24.8	11.3	31.8	22.6	23.3
n-6	13.1	8.9	10.4	17.7	13.0	10.0
n3/n6	1.8	2.7	1.1	1.8	1.7	2.3
Lipid %	3.5	5.2	8.9	4.5	5.7	5.1
Moisture (%)	78.37	69.3	54.37	72.0	74.6	73.0

Means in the same row , followed by different superscripts letters are significantly different ($p<0.05$).
(Means ± standard deviation n=3).

The major monounsaturated (MUFA) was oleic acid (C18:1), it ranged from 6.5% in morgan to 23.7% in bolty with mean value of 12.6, followed by eicosenoic acid (C20:1) and docosaenoic acid (C22:1) with mean values of 3.9% and 2.6% of total fatty acids, respectively.

Palmitic acid (C16:0) was the major saturated fatty acid ranging from 10.8 to 21.3% of the total fatty acids in morgan and hamor, followed by myristic acid (C14:0), stearic acid (C18:0) and arachidic acid (C20:0) in small amounts. Unidentified fatty acids called as "others" ranged from 3.2 in bory to 8.3% in shoar of the total fatty acids. In general, long chain PUFA n-3 were well retained by different cooking methods. No significant change ($P>0.05$) was observed in C22:6, C22:5, C20:3, C18:3 n-3 series PUFA in all the species after baking, steaming, boiling and microwave cooking.

However, a lower value of C20:3 and C18:3 were obtained after baking of hamor. A significantly higher ($P<0.05$) value of C22:6 was found in morgan after microwave cooking. It might be due to subcutaneous deposit of fat under the skin which was melted and absorbed by the edible portion of the sample during cooking. Significantly lower ($P<0.05$) percentages of PUFA n-3 were observed in all these species after frying reflecting the absorption of frying oil. No changes were observed in total n-3 PUFA after baking, steaming, boiling and microwave cooking in all six species. This study is in agreement with studies previously reported by Mai *et al.* [14], Asiedu and Agren and Hanninen [24 -25] showing that PUFA are not significantly destroyed in the process of baking, boiling, and microwave cooking.

Table 5. Lipid, moisture, (%), and fatty acid composition of lipids (% total lipids) in morgan fish as affected by cooking method

Fatty acid	Raw	Baking	Frying	Steaming	Boiling	Microwave
14:0	$1.6^{bc}\pm0.3$	$1.1^{cd}\pm0.4$	$0.8^{d}\pm0.1$	$2.7^{a}\pm0.5$	$1.5^{bcd}\pm0.2$	$2.1^{ab}\pm0.2$
16:0	$10.8^{c}\pm0.5$	$10.2^{cd}\pm3.1$	$21.7^{a}\pm0.8$	$12.3^{bc}\pm0.5$	$14.6^{b}\pm0.5$	$10.6^{bcd}\pm0.9$
18:0	$5.1^{a}\pm0.1$	$5.7^{a}\pm1.6$	$2.9^{b}\pm0.1$	$6.4^{a}\pm0.6$	$5.4^{a}\pm0.1$	$5.9^{a}\pm0.4$
20:0	$2.2^{a}\pm0.1$	$2.0^{a}\pm0.5$	$0.6^{c}\pm0.5$	$1.6^{ab}\pm0.6$	$0.2^{c}\pm0.1$	$1.0^{bc}\pm0.2$
TOTAL	19.7±1.0	19.0±5.6	26.0±1.5	23.0±2.2	21.7±0.9	19.6±1.7
16:1	$1.7^{c}\pm0.1$	$1.7^{c}\pm0.5$	$0.2^{d}\pm0.1$	$2.6^{ab}\pm0.2$	$3.1^{a}\pm0.4$	$2.0^{bc}\pm0.2$
18:1	$6.5^{c}\pm0.1$	$6.6^{c}\pm1.3$	$27.6^{a}\pm1.0$	$7.9^{c}\pm0.8$	$11.3^{b}\pm0.3$	$7.4^{c}\pm0.3$
20:1	$3.8^{a}\pm0.1$	$3.8^{a}\pm0.6$	$1.0^{b}\pm0.6$	$4.0^{a}\pm0.8$	$2.1^{b}\pm0.2$	$2.1^{b}\pm0.3$
22:1	$4.4^{a}\pm0.1$	$2.5^{a}\pm0.3$	2.0a±0.2	$2.6^{a}\pm0.4$	$2.8^{a}\pm1.9$	$4.7^{a}\pm0.1$
TOTAL	16.4±0.4	14.6±2.7	30.8±1.8	17.1±2.2	19.3±2.8	16.2±0.9
18:2 n-6	$2.8^{b}\pm0.3$	$5.7^{a}\pm1.2$	$7.1^{a}\pm0.7$	$2.0^{b}\pm1.2$	$1.6^{b}\pm0.1$	$1.9^{b}\pm0.2$
18:3 n-3	$2.5^{a}\pm0.1$	$2.3^{a}\pm0.5$	$0.8^{bc}\pm0.2$	$2.6^{a}\pm0.3$	$0.2^{c}\pm0.1$	$1.4^{b}\pm0.2$
20:2 n-6	$5.6^{a}\pm0.9$	$5.3^{a}\pm2.1$	$2.8^{a}\pm0.5$	$4.1^{a}\pm1.1$	$2.7^{a}\pm0.3$	$4.6^{a}\pm0.7$
20:3 n-3						
20:4 n-6	$10.3^{a}\pm0.4$	$11.0^{a}\pm1.5$	$6.2^{b}\pm1.0$	$9.0^{ab}\pm2.0$	$7.8^{ab}\pm0.5$	$9.1^{ab}\pm1.7$
20:5 n-3	$12.2^{a}\pm0.5$	$9.7^{a}\pm2.3$	$11.0^{a}\pm3.4$	$10.0^{a}\pm4.7$	$10.4^{a}\pm2.7$	$10.5^{a}\pm1.1$
22:4 n-6	$7.8^{a}\pm0.1$	$7.3^{a}\pm0.8$	$4.1^{b}\pm0.5$	$7.0^{a}\pm0.7$	$6.9^{a}\pm0.7$	$8.2^{a}\pm0.1$
22:5 n-3	$4.1^{a}\pm0.8$	$4.2^{a}\pm1.4$	$3.4^{a}\pm0.5$	$4.0^{a}\pm0.3$	$5.2^{a}\pm0.4$	$4.0^{a}\pm0.7$
22:6 n-3	$13.0^{b}\pm5.0$	$14.6^{ab}\pm3.6$	$4.1^{c}\pm0.4$	$17.1^{ab}\pm0.4$	$17.3^{ab}\pm0.1$	$18.1^{a}\pm1.3$
TOTAL	58.3±8.1	60.1±13.4	39.5±7.2	55.8±10.7	52.1±4.9	57.8±6.0
OTHERS	$5.6^{a}\pm2.8$	$6.2^{a}\pm2.0$	$3.7^{a}\pm0.6$	$6.0^{a}\pm1.3$	$6.8^{a}\pm0.6$	$6.3^{a}\pm0.7$
n-3	31.8	32.8	19.3	33.8	33.1	34.0
n-6	26.5	29.4	20.2	22.1	19.0	23.8
n-3/n6	1.2	1.1	1.0	1.5	1.7	1.4
Lipid, (%)	2.5	3.2	4.8	2.7	2.5	2.8
Moisture (%)	77.21	64.6	52.0	73.25	69.6	73.0

Means in the same row, followed by different superscripts letters are significantly different ($p<0.05$).
(Means ± standard deviation, n=3).

No significant difference ($P<0.05$) was shown in major PUFA C20:4 of n-6 series after baking, steaming, boiling and microwave cooking in all the species. However, a lower value ($P<0.05$) was observed in morgan, shaor, bory and bolty after frying. Whereas no change was found in fried hamor and kanad. This might be due to association with phospholipids which tend to retain stable during frying [26].

C20:2 and C18:2 n-6 series PUFA remain unchanged after cooking ($P<0.05$) except in frying. The fatty acid C20:2 was lost after frying whereas C18:2 n-6 increased possibly from cooking oil.

Table 6. Lipid,moisture, (%) and fatty acid compotion of lipids (% total lipid) in bolty fish , as affected by cooking method

Fatty acid	Raw	Baking	Frying	Steaming	Boiling	Microwave
14:0	$2.8^{ab}\pm0.4$	$2.6^{ab}\pm0.5$	$1.4^{ab}\pm0.1$	$3.0^{a}\pm0.1$	$2.1^{ab}\pm1.0$	$3.2^{a}\pm0.9$
16:0	$16.6^{b}\pm2.2$	$17.6^{b}\pm3.4$	$31.1^{a}\pm0.1$	$21.5^{b}\pm1.1$	$13.1^{a}\pm5.9$	$18.4^{b}\pm4.9$
18:0	$3.7^{a}\pm0.6$	$4.1^{a}\pm0.4$	$4.1^{a}\pm0.1$	$5.0^{a}\pm0.1$	$3.2^{a}\pm1.1$	$4.1^{a}\pm3.2$
20:0	$1.8^{ab}\pm0.7$	$3.0^{ab}\pm1.0$	$0.7^{b}\pm0.6$	$2.6^{ab}\pm0.9$	$4.1^{a}\pm2.0$	$1.4^{b}\pm0.4$
TOTAL	24.9±3.9	27.3±5.3	37.3±0.9	32.1±2.2	22.5±10.0	27.1±8.7
16:1	$5.2^{a}\pm0.6$	$5.7^{a}\pm1.2$	$2.0^{b}\pm0.5$	$6.9^{a}\pm0.1$	$4.9^{a}\pm1.5$	$6.2^{a}\pm1.8$
18:1	$23.7^{ab}\pm3.6$	$24.4^{ab}\pm 3.5$	$34.8^{a}\pm3.2$	$27.7^{ab}\pm0.3$	$19.7^{b}\pm6.2$	$24.3^{ab}\pm2.9$
20:1	$3.4^{a}\pm1.4$	$4.7^{a}\pm0.3$	$1.1^{b}\pm1.0$	$2.2^{ab}\pm0.6$	$4.0^{ab}\pm2.1$	$3.4^{ab}\pm0.5$
22:1	$2.2^{a}\pm2.3$	$2.1^{a}\pm0.1$	$0.3^{a}\pm0.1$	$1.2^{a}\pm0.3$	$2.6^{a}\pm0.80$	$3.0^{a}\pm2.2$
TOTAL	34.5±7.9	36.9±5.1	38.2±4.8	38.0±1.3	31.2±10.6	36.9±7.4
18:2 n-6	$10.0^{a}\pm1.5$	$11.6^{a}\pm1.5$	$9.6^{a}\pm2.1$	$11.6^{a}\pm0.3$	$7.9^{a}\pm3.4$	$10.2^{a}\pm2.9$
18:3 n-3	$1.5^{a}\pm0.7$	$2.4^{a}\pm0.9$	$0.8^{a}\pm0.5$	$1.6^{a}\pm0.7$	$2.4^{a}\pm1.1$	$1.1^{a}\pm0.2$
20:2 n-6	$2.8^{a}\pm0.6$	$2.7^{a}\pm1.2$	$0.7^{b}\pm0.6$	$2.1^{ab}\pm0.9$	$1.8^{ab}\pm0.3$	$2.2^{ab}\pm0.6$
20:3 n-3	$2.6^{a}\pm0.2$	$2.2^{a}\pm0.8$	$0.7^{b}\pm0.2$	$1.3^{ab}\pm0.1$	$1.7^{ab}\pm0.6$	$1.9^{a}\pm0.3$
20:4 n-6	$3.9^{a}\pm0.2$	$4.0^{a}\pm1.5$	$1.4^{ab}\pm0.1$	$3.6^{a}\pm0.2$	$3.7^{a}\pm0.8$	$3.0^{ab}\pm0.5$
20:5 n-3	$6.1^{a}\pm1.7$	$6.5^{a}\pm3.0$	$5.0^{a}\pm2.9$	$2.3^{a}\pm0.8$	$6.9^{a}\pm3.7$	$5.2^{a}\pm4.9$
22:4 n-6	$2.6^{a}\pm2.1$	$1.3^{a}\pm0.7$	$1.4^{a}\pm1.4$	$1.0^{a}\pm0.2$	$4.3^{a}\pm2.0$	$2.7^{a}\pm2.0$
22:5 n-3	$2.4^{a}\pm2.1$	$1.0^{a}\pm0.3$	$1.2^{a}\pm1.2$	$1.0^{a}\pm0.4$	$4.1^{a}\pm2.5$	$2.8^{a}\pm2.7$
22:6 n-3	$3.1^{ab}\pm3.5$	$2.3^{b}\pm1.1$	$2.2^{b}\pm2.0$	$4.1^{ab}\pm0.1$	$9.0^{a}\pm4.0$	$3.8^{ab}\pm3.1$
TOTAL	35.0±12.6	34.0±11.0	23.0±11.0	27.8±3.7	41.8±18.4	32.9±17.2
OTHERS	$5.5^{a}\pm1.8$	$1.6^{a}\pm0.1$	$1.4^{a}\pm1.7$	$1.3^{a}\pm0.1$	$4.3^{a}\pm0.8$	$3.0^{a}\pm3.0$
n-3	15.7	15.3	9.9	10.3	24.1	14.9
n-6	19.3	19.6	13.3	18.3	18.1	18.1
n3/n6	0.8	0.7	0.7	0.5	1.3	0.8
Lipid %	4.4	4.7	8.8	4.3	4.2	5.8
Moisture (%)	77.73	66.4	57.36	73.0	74.6	73.2

Means in the same row, followed by different superscripts letters significantly different ($p<0.05$).
(Means ± standard deviation, n=3).

Significantly lower ($P < 0.05$) percentage of C16:1, C20:1, C22:1 and higher level of C18:1 were found in all species in fried fillets as compared to raw fillets and fillets cooked by all other methods. Similarly unidentified "others" fatty acid and C16:0 were also found higher ($P<0.5$) after frying in all the species under investigation. Other saturated fatty acids C14:0, C18:0 and C20:0 showed no differences ($P<0.05$) after cooking in all the species under investigation.

With regards to n-6 PUFA for species such as shoar, bory, morgan, and bolty, their fillets contained more than 10% of the total fatty acids. The major n-6 fatty acid present was C20:4, other FA of the n-6 series present include 20:2 and 22:4 which decreased in fried shaor, hamor, morgan, and bolty had been found. With regards to n-3 PUFA, kanad, shoar, hamor, bory, and morgan all contained more than 23% n-3 PUFA, bolty were lowest in percentage of n-3 PUFA had 16%. In general n-3 PUFA were well retained in different cooking methods. Their content in flesh decreased in most species during frying. Slight increase was found only in baked and boiled shoar. The greatest decrease in n-3 PUFA took place in fried species where about 50% decrease were found. The ratio of n-3/n-6 PUFA was mostly one for shoar, morgan, and bolty while for other species it was higher. However all cooking methods had slight effect on n-3/n-6 PUFA ratio in all species, and all cooking methods can be used without significant loss. When cooking oil is used for frit should not interfere with biological effect on n-3 PUFA. Fish rich in n-3 PUFA have been proposed as antithrombotic dietary supplements [27-28]. Oil rich in n-3 would provide substrates for the synthesis of platelet antiaggregatory factor such as thromboxane and prostacylin of the 3-series. The use of fish or fish oils rich in both n-3 and n-6 PUFA may provide a more balanced dietary approach especially when the potentially deleterious effect of fish oil feeding is considered [29].

In conclusion that the amount of moisture and lipid lost during cooking in non lipid environments appeared to be influenced by the original lipid content of the fillet. The amount of lipid absorbed by a fillet cooked in oil decreased as the original lipid content of the fish increased. Fried fillets absorbed the major fatty acid in the cooking medium which resulted in a relative decrease in the percentage of other fillet fatty acids.

References

[1] Knisella, J.E. *Seafoods and Fish Oils in Human Health and Dieases*. New York: Marcel Dekker, 1987.

[2] Singh, G. and Chandra, R.K. "Biochemical and Cellular Effects of Fish and Fish Oils". *Prog. Food Nutr. Sci.*, 12 (1988), 371-419.

[3] Lees, R.S. and Karel, M. *Omega-3 Fatty Acids in Health and Disease*. New York: Marcel Dekker, 1990.

[4] Stansby, M.E. "Nurtional Properties of Fish Oil For Human Consumption, Modern. Aspect." In: *Fish Oils in Human Nutrition*. M.E. Stansby (Ed.). New York: AVI, 1990.

[5] Kinsella, J.E., Lokesh, B., and Stone, R.A. "Dietary N-3 Polyunsaturated Fatty Acid and Amelioration of Cardiovascular Disease: Possible Metabolism". *Am. J. Clin. Nutr.*, 52 (1990), 1-28.

[6] Harris, W.S. "Fish Oil and Plasma Lipid and Lipoprotein Metabolism in Humans: A Critical Review". *J. Lipid Res.*, 30 (1989),785-807.

[7] Simopoulos, A.P. "Summary of the NATO Advanced Research Workshop on Dietary ω3 and ω6 Fatty Acids: Biological Effects and Nutritional Essentiality". *J. Nutrition,* 119 (1989), 521-528.

[8] Mest, H.J., Beitz, J., Heinroth, I., Block, H.U. and Foster, W. "The Influ of Linseed Oil Diet on Fatty Acid Pattern in Phosphilipids and Thromboxane Formation in Platelets in Man". *Klin. Wochenschr.*, 61 (1983),187.

[9] Renaud, S., Dumont, E., Godsey, F., Morazian, R., Thevenon, C. and Ortchanian, E. "Dietary Fats and Platelet Function in French and Scottish Farmers". *Nutr. Metabol.*, 24 (Supple. 1), (1980),90-104.

[10]Renaud, S. and Nordoy, A. "Small is Beautiful: Alpha-Linolenic Acid and Eicosapentaenoic Acid in Man". *Lancent.*, 21 May, (1983), 1169.

[11] Singer, P., Jaeger, W., Wirth, M., Voigt, S., Naumann, E., Zimontkowski, S., Hajdn. and Goedicke, W. "Lipid and Blood Pressure Lowering Effect of Mackerel Diet in Man". *Atherosclerosis.*, 49 (1983), 99.

[12] Herold, P. and Kinsella, J.E. "Fish Oil Consumption and Decreased Risk of Cardiovascular Disease: A Comparison of Findings from Animal and Human Trials". *Am. J. Clin. Nutr.*, 43 (1986), 566-598.

[13] Ackman, R.G. "Nutritional Composition of Fats in Seafoods". *Prog. Food Nutr. Sci.*, 13 (1989), 161-241.

[14] Mai, J., Shimp, J., Weihrauch, J. and Kinsella, J.E. "Lipid of Fish Fillets: Changes Following Cooking by Different Methods". *J. Food Sci.* 43 (1978),1669-1674.

[15] Gall, K.L., Otwell, W.S., Koberger, J.A. and Appledorf, H. "Effects of Four Cooking Methods on the Proximate Mineral and Fatty Acid Composition of Fish Fillets". *J. Food Sci.*, 48 (1983), 1068-1074.

[16] Hearn,T.L., Sgoutas, S.A., Sgoutas, D.S. and Hearn, J.A. "Stability of Polyunsaturated Fatty Acids after Micro Wave Cooking of Fish". *J. Food Sci.*, 52 (1987),1430-1431.

[17] Folch, J., Lee, M. and Slone-Stanley, G.H. "A Simple Method for the Isolation and Purification of Total Lipids from Animal Tissues". *J. B.C.* 226 (1957), 497-509.

[18] Metcalf, L.E., Schmitz, A.A. and Pelca, J.R. "Rapid Purification of Fatty Acid Esters from Lipid for Gas Chromatographic Analysis." *Anal. Chem.*, 38 (1966), 514-515

[19] *SAS User's Guide, Statistical Analysis System.* SAS Institute Inc., Box 8000, Carry NC. 27211-8000, USA. (1986).

[20] Steel, E.G.D. and Torrie, J.H. *Principles and Procedures of Statistics.* New York: Mcgraw-Hill Book Company Inc., USA.1980.

[21] Love, R.M. *"The Biochemical Composition of Fish".* In: *The Physiology of Fishes.* New York: Academic Press (1957), 401-418.

[22] Stansby, M.E. and Olcott, H.S. *"Composition of Fish Industrial Fishery Tehcnology"* . New York: Reinholt Pub. Co. (1963), 339-349.

[23] Sinclair, A., Dustan, G.A., Nughton, J.M., Sanigorski, A.J. and O'Dea. K. "The Lipid Content and Fatty Acid Composition of Commercial Marine and Fresh-Water Fish and Molluscs from Temperate Australian Waters". *Australian Journal of Nutrition and Dietetics.*, 49, No. 3 (1992), 77-83.

[24] Asiedu, M .S., Julshamn. and Lie, O. "Effects of Local Processing Methods (Cooking, Frying, Smoking) on Three Fish Species from Ghana : Part 1. Proximate Composition , Fatty Acids, Minerals, Trace Elements and Vitamins". *Food Chem.*, 40 (1991), 309-321.

[25] Agren, J.J. and Hanninen, O. "Effects of Cooking on the Fatty Acids of Three Fresh Water Fish Species". *J. Food Chem.*, 46 (1993), 377-382.

[26] Lee, W.T. and Dawson, L.E. "Changes in Phospholipids in Chicken Tissues During Cooking in Fresh And Reused Cooking Oil and during Frozen Storage". *J. Food Sci.*, 41 (1976), 598 -600.

[27] Budowski, P. "Nutritional Effects of N-3 Polyunsaturated Fatty Acids". *Isr. J. Med Sci.*, 17 (1981), 223-231.

[28] Goodnight, S.H. Jr.; Harris, W.S., Connor, W.E. and Illingworth, R.D. "Polyunsaturated Fatty Acids, Hyperlipidemia and Thrombosis". *Arteiosclerosis.*, 2 (1982), 87-113.

[29] Goodnight, S.H., Jr., Harris, S.W., Conner, W.E. and Illingworth, R.D. "The Effect of Dietary N-3 Fatty Acids on Platelet Composition and Function in Man: A Prospective Controlled Study". *Blood.*, 58 (1981), 880-885.

تأثير الطبخ بطرق مختلفة على الأحماض الدهنية متعددة اللاّ إشباع في ستة أنواع من الأسماك

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ملخص البحث. تمت دراسة تأثير طبخ بعض الأسماك على محتوى وثباتية الأحماض الدهنية وقد استخدمت في الدراسة طرق الطبخ التالية: تحميص ، قلي في زيت النخيل ، تبخير ، غلى ، ميكروويف ، على ست أنواع من الأسماك (الكنعد ، الشعور ، هامور' البوري ، المورجان والبلطي). ومن الدراسة وجد أن محتوى n-3 PUFA في جميع الأسماك المدروسة كان أكثر من ٢٣% من الليبيدات ماعدا في سمك البلطي فقد احتوت على ١٦%. وأن ذلك المحتوى تناقص في معظم الأسماك المدروسة أثناء عملية القلي. بلغت نسبة n3/n6 حوالي واحد في سمك المورجان ، الشعور ، والبلطي ، بينما كانت في الأسماك الأخرى أكثر من واحد. ومن نتائج هذه الدراسة وجد أنه يمكن استخدام جميع طرق الطبخ بدون فقدان نسبة الـ n3/n6 PUFA خاصة إذا كان زيت القلي لايتداخل مع التأثيرات الحيوية للأحماض الدهنية من نوع (n-3) أوميجا ٣.