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NUTRITIONAL VALUE AND FATTY ACIDS COMPOSITION IN THE MOST COMMON EGYPTIAN FISH AS AFFECTED BY TRADITIONAL GRILLING PROCESS

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ABSTRACT

This research was carried out to study the impact of the traditional grilling process on the nutritional value and fatty acids composition of the most common Egyptian fish (Tilapia, Mullet and Sardine). The obtained results showed a decrease in moisture, ash and oil in grilled fish as a result of grilling process, where crude oil decreased from 22.14% to 11.40% (based on dry weight) in Mullet fish. While, crude protein increased from 69.04% to 86.71% (based on dry weight) in Mullet fish, too. As for fatty acids composition, decrease percentage of saturated fatty acids were 4.25% and 2.35% for Sardine and Tilapia, respectively, while this percentage increased in Mullet fish by 6.25% of saturated fatty acids. Also, monounsaturated fatty acids percentage decreased in Sardine and Mullet fish by 3.84% and 11.72%, respectively. Polyunsaturated fatty acids increased in all types of fish by various percentages. Total unsaturated fatty acids/ total saturated fatty acids ratio of fish oils increased in both Sardine and Tilapia, where the rise percentage were 9.76% and 4.6%, respectively, while decrease percentage of this ratio in Mullet fish was 9.55%. Results of this study has shown that the common Egyptian fish were very poor in polyunsaturated fatty acids content, especially the omega-3 (EPA and DHA). So, it is recommended to increase consumption of other types of fish which are rich in these fatty acids.

Keywords: Fish grilling process, chemical composition, nutritional value, and fatty acids profile.

INTRODUCTION

The consumption of fish has been linked to health benefits, a reduced risk of coronary heart disease, arterial hypertension, human breast cancer growth, inflammatory diseases, asthma and disorders of immune system *(Uauy and Valenzuela, 2000)*.

With more than 30,000 known species, fish form the biggest group in the animal kingdom that is used for the production of animal-based foods. Only about 700 of these species are commercially fished and used for food production. Further, some 100 crustacean and 100 molluscan species (for example mussels, snails and cephalopods) are used as food for humans. The amount captured worldwide is registered annually by the Food and Agriculture Organization of the United Nations *(Rehbein and Oehlenschläger, 2009)*.

World fisheries production, by capture and aquaculture reached 142 million tons at 2008, China came at the first order , where it annually produced 47.5 million tons represented about 33.45% of world production. Egypt came at the first order between Arab countries, where it produced about million ton annually (0.7% of world production). As for world aquaculture production of fish, Egypt came at 11th order (693 thousands tons). While as world capture production, Egypt came at 40th order (374 thousands tons) *(FAO 2008)*.

Fish and other seafood are very important in covering a part of the protein demand for humans. In 2000, food fish contributed 15.9% to the human diet on a worldwide basis (fish as a percentage of total animal protein intake). There are, however, great differences between continents and countries. In low-income, food-deficient countries (LIFDC) fish contributes 20.6%, in Asia 23.3%, in China 21.1%, whereas in South America the contribution amounts only to 5.7%, in North and Central America to 7.1% and in Europe to 10.3%. The average contribution in developed countries is 12% whereas it is 18.8% in developing countries *(FAO, 2004)*.

Fish lipids differ from those of terrestrial animals mainly in their high content of long chain, highly unsaturated fatty acids of the n–3 series (eicosapentaenoic acid, 20:5 and docosahexaenoic acid, 22:6), often referred to as polyunsaturated fatty acids (PUFAs). The content of these PUFAs in fatty fish species can be high: dogfish 3 g/100g, herring 2.3 g/100g, mackerel 4.6 g/100g, salmon 2.3 g/100g and tuna 2.1 g/100g. The highly unsaturated character of these fatty acids is the reason why they are susceptible to lipid oxidation and oxidative degradation. Fatty fish species therefore have a tendency to exhibit rancid tastes and odours after limited storage time *(Rehbein and Oehlenschläger, 2009)*.

Gokoglu et al. (2004) studied the effects of different cooking methods (frying, boiling, baking, grilling, microwave cooking) on proximate composition and mineral contents of rainbow trout (*Oncorhynchus mykiss Walbaum 1792*). They found that mean moisture, protein, ash and fat contents of raw fish were 73.38%, 19.8%, 1.35% and 3.44%, respectively. The changes in dry matter, protein and ash contents were found to be significant for all cooking methods. The results indicated that cooking had considerable affect on the proximate composition and mineral contents. Baking and grilling were found to be the best cooking methods for healthy eating.

Saldanha and Bragagnolo (2008) studied the effect of different types of packing during frozen storage of Atlantic hake fillets and subsequent grilling on lipid composition and cholesterol oxidation. They found that the moisture levels and amount of lipids decreased after grilling and there was a significant decrease in the content of polyunsaturated fatty acids in all hake samples.

So, this study was done to study the effect of traditional grilling process on gross chemical composition and fatty acids profiles, mainly omega-3 fatty acids (EPA and DHA), in the most common Egyptian fish namely Sardine, Tilapia and Mullet.

MATERIALS AND METHODS

Materials:

The most common Egyptian fish, Sardine (*Sardinella aurita, Valenciennes, 1847*), Grey Mullet (*Mugil cephalus, Linnaeus, 1758*) and Nile Tilapia (*Oreochromis niloticus niloticus, Linnaeus, 1758*) were purchased from fish local market, Damietta city, Egypt during October 2010. The fish weight means were 65, 145 and 200g, respectively.

Methods:

Grilling process:

Each sample of fresh fish was washed with tap water several times to remove slime and then were coating with wood dust and grilled on hot plate for 20 min. as a traditional grilling method.

After this traditional grill, grilled fish were cooled at room temperature. Then raw and grilled fish samples were filleted to produces fish flesh only (edible portions), homogenized using a kitchen blender to produce a representative samples and chemically analyzed.

Chemical analysis:

Moisture, ash, crude protein and crude oil contents were determined according to the method described by *AOAC (1990)*. Crude oil was extracted according to *Bligh and Dyer (1959)*.

Fatty acids composition of fish fat samples were analyzed out in The Central Laboratory Unit, High Institute of Public Health, Alexandria University, Egypt. Fatty acid methyl esters were prepared according to the procedure of Radwan (1978). The different fatty acid methyl esters (FAMEs) were determined an identified using a gas chromatography (HP 6890) equipped with a flame ionization detector (FID). A HP-5 column (30 m) [5% dimethyl 95% diphenyl polysiloxane] was used. The detector and injector temperatures were 250ºC and 220ºC, respectively. Sample size was 1 µl. Helium was used as a carrier gas at a flow rate of 0.8 ml/min. Oven temperature was programmed as:

- set point (initial temperature) 150ºC for 1 Min.
- rate 10ºC/Min. to 200ºC.
- rate 5ºC/Min. to 250ºC and hold for 4 Min.

A standard mixture of methyl esters was used.

RESULTS AND DISCUSSION

Gross chemical composition of studied raw and grilled fish samples are in Table (1). From these results, it could be noticed that grilling process reduced moisture content in all fish samples under investigation. For example, moisture content of sardine fish decreased from 72.80% to 66.10% as affected by grilling process with a decrease of 9.20%. Also, it could be reported that moisture content of Tilapia fish was the highest in both raw and grilled form (76.75% and 69.90%, respectively).

Table (1): Effect of grilling process on chemical composition of the most common Egyptian fish:

Component		Moisture %	Ash %		Crude oil %		Crude protein %	
Fish samples			***ww***	***dw***	***ww***	***dw***	***ww***	***dw***
Sardine	**Raw**	72.80	2.95	10.88	1.08	4.00	23.59	86.71
	Grilled	66.10	2.20	6.50	1.14	3.37	30.56	90.15
Mullet	**Raw**	68.35	2.80	8.87	7.00	22.14	21.85	69.04
	Grilled	66.05	1.27	3.77	3.87	11.40	29.44	86.71
Tilapia	**Raw**	76.75	1.90	8.24	2.81	12.1	18.32	78.80
	Grilled	69.90	0.69	2.32	1.00	3.33	28.41	94.39

(ww) means wet weight and(dw) means dry weight.

These previous results concerning to moisture content could be explained that the high temperature used during grilling process helps to evaporate water from fish tissues. The loss of moisture during grilling is time, heating temperature, size and thickness of the fillets dependent.

As for ash content, it could be seen that ash content decreased a affected by grilling process, where it decreased from 8.87% to 3.77% (*dw basis*) in mullet fish with a decrease of 57.50%. Raw sardine fish had the highest ash content on dry weight basis which it was 10.88%. These decreases in ash could be due to some minerals diffusion from fish tissues.

Crude oil content decreased after grilling process in all fish samples, where it decreased from 22.14% to 11.40% (*dw basis*) with a decrease of 48.51% in mullet fish, which represented the highest crude oil content between the three fish samples. These decreases in crude oil content may be due to the high temperature used in grilling process and the low melting point of such fish oil and this explanation will be very clear during fatty acids composition discussion. These findings were in agreement with results obtained by *Gokoglu et al. (2004) and Saldanha and Bragagnlo, (2008)*.

There is consensus that during grilling a loss in oil occurs due to dripping, although the amount lost depends on the temperature and time of grilling (*Saldanha and Bragagnlo, 2008*).

However, the lipid components of fish can vary according to the month of capture, the season and the particular area of sea (*Ga´mez-Meza et al., 1999*).

Finally, crude protein content of all fish samples increased as a results of grilling process. Crude protein of Tilapia fish increased from 78.80% to 94.39% (*dw* basis) after grilling process with an increase of 19.78%, but in Sardine and Tilapia the increase percentage was 3.96%and 25.6%, respectively. These increases in crude protein ratios could be explained as all nutrients reduction such as moisture, ash and crude oil lead to crude protein increase.

These results were in a good agreement with those obtained by *Saldanha and Bragagnlo (2008)* and *Me´ndez and Gonza´lez (1997)*.

Fatty acids composition of Sardine fish flesh as affected by grilling process was illustrated at Table (2). From these results, it could be reported that grilling process reduced saturated fatty acids percentage, where it decreased from 30.82% to 29.51% representing -4.25% as a change percentage. Palmitic acid ($C_{16:0}$) and stearic acid ($C_{18:0}$) were the most predominant of saturated fatty acids, where they were 23.877% and 5.236%

in raw Sardine fish, respectively. Palmitic acid decreased by 6.5% and stearic acid increased by 5.1% after grilling process.

Table (2): Effect of grilling process on fatty acids composition of Sardine fish flesh:

Fatty acids	g/100g oil		Change %	% of total fatty acid		Change %
	Raw	Grilled		Raw	Grilled	
$C_{6:0}$	0.044	0.066	50.0	0.036	0.051	41.67
$C_{8:0}$	0.029	0.033	13.8	0.023	0.025	8.70
$C_{10:0}$	0.097	0.028	-71.1	0.077	0.022	-71.43
$C_{12:0}$	0.165	0.119	-27.9	0.132	0.092	-30.30
$C_{13:0}$	0.036	0.022	-38.9	0.029	0.017	-41.38
$C_{14:0}$	0.069	0.046	-33.3	0.055	0.036	-34.55
$C_{15:0}$	0.763	0.727	-4.7	0.610	0.560	-8.20
$C_{16:0}$	29.887	28.985	-3.0	23.877	22.326	-6.50
$C_{17:0}$	0.497	0.560	12.7	0.397	0.431	8.56
$C_{18:0}$	6.554	7.145	9.0	5.236	5.503	5.10
$C_{20:0}$	0.400	0.481	20.3	0.320	0.371	15.94
$C_{21:0}$	0.039	0.039	0.0	0.031	0.030	-3.23
$C_{22:0}$	0.000	0.063	-	0.000	0.049	-
Σ(Saturated)	38.58	38.31	-0.7	30.82	29.51	-4.25
$C_{14:1}$	0.163	0.105	-35.6	0.130	0.081	-37.69
$C_{15:1}$	0.071	0.018	-74.6	0.057	0.014	-75.44
$C_{16:1\ \omega\text{-}7}$	17.293	16.796	-2.9	13.815	12.937	-6.36
$C_{17:1}$	0.156	0.247	58.3	0.125	0.190	52.00
$C_{18:1\ \omega\text{-}9}$	10.475	10.665	1.8	8.368	8.215	-1.83
$C_{20:1\ \omega\text{-}11+\ \omega\text{-}9}$	9.481	9.582	1.1	7.574	7.381	-2.55
$C_{22:1\ \omega\text{-}11+\ \omega\text{-}9}$	0.701	0.823	17.4	0.560	0.634	13.21
Σ(Monounsaturated)	38.34	38.24	-0.3	30.63	29.45	-3.84
$C_{18:2\ \omega\text{-}6}$	7.666	7.232	-5.7	6.125	5.571	-9.04
$C_{18:3\ \omega\text{-}3}$	0.791	1.168	47.7	0.632	0.899	42.25
$C_{20:2\ \omega\text{-}6}$	1.380	4.725	242.4	1.103	3.640	230.01
$C_{20:3\ \omega\text{-}3}$	2.244	8.550	281.0	1.792	6.586	267.52
$C_{20:4\ \omega\text{-}3}$	4.850	0.505	-89.6	3.874	0.389	-89.96
$C_{20:5\ \omega\text{-}3}$	0.182	0.000	-100.0	0.146	0.000	-100.00
$C_{22:2}$	1.225	2.162	76.5	0.979	1.665	70.07
$C_{22:6\ \omega\text{-}3}$	0.263	0.266	1.1	0.210	0.205	-2.38
Σ(Polyunsaturated)	18.60	24.61	32.3	14.86	18.96	27.55
Total unsaturated	56.94	62.85	10.38	45.49	48.41	6.42
ω-3/ω-6	0.92	0.88	-4.66	0.92	0.88	-4.66
Biological Value*	1.48	1.64	9.76	1.48	1.64	9.76

*** Biological value means total unsaturated fatty acids / total saturated fatty acids.**

As for monounsaturated fatty acids, it was constant and did not change as affected by grilling process. Monoenes was 30.63% and 29.45% in raw and grilled Sardine fish, respectively. ($C_{16:1\ \omega\text{-}7}$) was the highest monounsaturated fatty acid (13.815% in raw and 12.937% in grilled), while oleic acid ($C_{18:1\ \omega\text{-}9}$) was in the second order, where it represented 8.368% and 8.215% in both raw and grilled forms, respectively. Also, ($C_{20:1\ \omega\text{-}11+\ \omega\text{-}9}$) was 7.574% and 7.381% in the same both forms.

Grilling process caused an increase in polyunsaturated fatty acids content due to the decrease in saturated fatty acid during grilling as shown in Table (2), where it increased from 14.86% in raw Sardine fish to 18.96% after grilling process. The most predominant polyunsaturated fatty acid was linoleic acid ($C_{18:2\ \omega-6}$), which represented 6.125% and 5.571% in raw and grilled fish, respectively. Egyptian raw and grilled Sardine fish was poor in omega-3 fatty acids especially ecosapentanoic acid (EPA) and decosahexanoic acid (DHA), where they were 0.146% and 0.210%, respectively. Total unsaturated fatty acids content increased after grilling process, where it changed from 45.49% to 48.41%. And consequently, total unsaturated fatty acids/ total saturated fatty acids ratio, biological value, *(Dailel, 1964)* of this oil increased by 9.76% as a change percentage. As omega-3/omega-6, it decreased by 4.66% as a change percentage after grilling process (Table 2).

The lipid components and contents of fish vary according to the species, age, location, species origin characteristics, such as spawning and migration seasons, and also some environmental conditions, such as temperature *(Huss, 1988)*.

Fatty acids composition of Mullet fish flesh as affected by traditional grilling process is presented in Table (3).

Table (3): Effect of grilling process on fatty acids composition of Mullet fish flesh:

Fatty acids	g/100g oil		Change %	% of total fatty acid		Change %
	Raw	Grilled		Raw	Grilled	
$C_{6:0}$	0.027	0.044	62.96	0.026	0.044	69.23
$C_{8:0}$	0.025	0.023	-8.00	0.024	0.023	-4.17
$C_{10:0}$	0.140	0.020	-85.71	0.133	0.020	-84.96
$C_{12:0}$	0.011	0.031	181.82	0.011	0.031	181.82
$C_{13:0}$	0.078	0.117	50.00	0.074	0.117	58.11
$C_{14:0}$	4.826	4.789	-0.77	4.577	4.771	4.24
$C_{15:0}$	1.093	1.235	12.99	1.037	1.230	18.61
$C_{16:0}$	22.522	22.475	-0.21	21.359	22.388	4.82
$C_{17:0}$	0.894	0.869	-2.80	0.848	0.865	2.00
$C_{18:0}$	2.935	3.338	13.73	2.783	3.326	19.51
$C_{20:0}$	0.350	0.327	-6.57	0.332	0.325	-2.11
$C_{21:0}$	0.026	0.040	53.85	0.025	0.040	60.00
Σ(Saturated)	32.927	33.308	1.16	31.229	33.180	6.25
$C_{14:1}$	0.102	0.105	2.94	0.097	0.105	8.25
$C_{15:1}$	0.069	0.086	24.64	0.066	0.086	30.30
$C_{16:1\ \omega-7}$	12.215	12.527	2.55	11.584	12.479	7.73
$C_{17:1}$	0.536	0.492	-8.21	0.508	0.491	-3.35
$C_{18:1\ \omega-9}$	5.893	3.291	-44.15	5.589	3.278	-41.35
$C_{20:1\ \omega-11+\ \omega-9}$	4.953	3.390	-31.56	4.697	3.377	-28.10
$C_{22:1\ \omega-11+\ \omega-9}$	1.324	1.197	-9.59	1.256	1.192	-5.10
Σ(Monounsaturated)	25.092	21.088	-15.96	23.797	21.008	-11.72
$C_{18:2\ \omega-6}$	25.226	23.310	-7.60	23.924	23.220	-2.94
$C_{18:3\ \omega-3}$	1.256	0.982	-21.82	1.192	0.978	-17.95
$C_{20:2\ \omega-6}$	2.881	2.203	-23.53	2.732	2.195	-19.66
$C_{20:3\ \omega-3}$	1.460	2.361	61.71	1.385	2.352	69.82
$C_{20:4\ \omega-3}$	1.289	1.885	46.24	1.223	1.878	53.56
$C_{20:5\ \omega-3}$	0.135	0.329	143.70	0.128	0.328	156.25
$C_{22:2}$	1.041	1.353	29.97	0.987	1.348	36.58
$C_{22:6\ \omega-3}$	0.195	0.205	5.13	0.185	0.204	10.27
Σ(Polyunsaturated)	33.483	32.628	-2.55	31.756	32.503	2.35
Total unsaturated	58.575	53.716	-8.30	55.553	53.511	-3.68
ω-3/ω-6	0.154	0.226	46.75	0.154	0.226	46.75
Biological Value*	1.78	1.61	-9.55	1.78	1.61	-9.55

*** Biological value means total unsaturated fatty acids / total saturated fatty acids.**

Palmitic acid ($C_{16:0}$) was the main saturated fatty acid in raw Mullet fish, where it was 21.359% and reached 22.388% after grilling with an increase of 4.82%. Myristic acid ($C_{14:0}$) came in the second order between saturated fatty acids. It increased after grilling process with an increase of 4.82%. Stearic acid ($C_{18:0}$) came in the third order, where it was 2.783% and 3.326% in raw and grilled Mullet fish, respectively. So, total saturated fatty acids content increased after grilling process, where it changed from 31.229% to 33.180% with an increases of 6.25% (Table 3).

As monounsaturated fatty acids, monoenes decreased from 23.797% in raw Mullet fish form to 21.008% in grilled form with a decrease of 11.72%. ($C_{16:1\ \omega\text{-}7}$) came in the first order, where it was 11.584% and 12.479% in raw and grilled Mullet fish form, respectively. While oleic acid ($C_{18:1\ \omega\text{-}9}$) came in the second order. It decreased as affected by grilling process with decrease of 41.35%. Also, $C_{20:1\ \omega\text{-}11+\ \omega\text{-}9}$ had clear value which represented 4.697% and 3.377% in raw and grilled Mullet fish form, respectively (Table 3).

Finally, polyunsaturated fatty acids increased from 31.756% to 32.503% as affected by grilling process. Linoleic acid ($C_{18:2\ \omega\text{-}6}$) was the main polyunsaturated fatty acid. It represented 23.924% and 23.220% in raw and grilled Mullet fish, respectively. While EPA and DHA were very low in Mullet fish. EPA was 0.128% and 0.328% in raw and grilled Mullet fish, respectively. DHA was 0.185% in raw fish and 0.204% in grilled Mullet fish.

So, total unsaturated fatty acids content decreased from 55.553% in raw Mullet fish to 53.511% in grilled Mullet fish with a decrease of 3.68%. Subsequently, biological value *(Dailel, 1964)* decreased also with a decrease of 9.55%. ω-3/ω-6 ratio was very small, where it was 0.226 in grilled Mullet fish. These results were in a good agreement with those obtained by *Saldanha and Bragagnlo (2008).*

Other authors reported a decrease of ω-3/ω-6 during different heat treatments of fish samples *(Gladyshev et al., 2006 and Gladyshev et al., 2007)*.

Fatty acids composition of Tilapia fish flesh as affected by traditional grilling process is presented in Table (4). Total saturated fatty acids content decreased from 33.347% to 32.563% as affected by grilling process. Palmitic acid ($C_{16:0}$) was the main saturated fatty acid, where it was 22.194% in raw Tilapia fish flesh.

Stearic acid ($C_{18:0}$) came in the second order of saturated fatty acids. It increased by 11.18% after grilling process. While, myristic acid ($C_{14:0}$) came in the third order, where it decreased from 4.086% to 3.365% after grilling.

As for monounsaturated fatty acid content, it was 17.838% and 18.284% in raw and grilled Tilapia fish flesh, respectively. Oleic acid came in the first order of monoenes, where it was 9.362% and 10.213% in raw and grilled Tilapia, respectively. $C_{16:1\ \omega\text{-}7}$ came in the second order, its content decreased from 5.660% to 5.176% as affected by grilling process. $C_{20:1\ \omega\text{-}11+\ \omega\text{-}9}$ increased from 1.875% to 2.078% after grilling process (Table 4).

Form the same Table it is noticeable that, Linoleic acid ($C_{18:2\ \omega\text{-}6}$) came in the first order of polyunsaturated fatty acids. Its content reached 37.633% in raw form and 38.000% in grilled form with increase of 0.98%.

While, omega-3 fatty acids (EPA and DHA) were very small amounts, did not exceed 1.0% and thus, there is no clear effect of grilling process.

Table (4): Effect of grilling process on fatty acids composition of Tilapia fish flesh:

Fatty acids	g/100g oil		Change %	% of total fatty acid		Change %
	Raw	Grilled		Raw	Grilled	
$C_{6:0}$	0.109	0.055	-49.54	0.096	0.044	-54.17
$C_{8:0}$	0.020	0.024	20.00	0.018	0.019	5.56
$C_{10:0}$	0.036	0.020	-44.44	0.032	0.016	-50.00
$C_{12:0}$	0.449	0.008	-98.22	0.397	0.006	-98.49
$C_{13:0}$	0.040	0.036	-10.00	0.035	0.029	-17.14
$C_{14:0}$	4.618	4.188	-9.31	4.086	3.365	-17.65
$C_{15:0}$	0.540	0.540	0.00	0.477	0.434	-9.01
$C_{16:0}$	25.083	27.582	9.96	22.194	22.165	-0.13
$C_{17:0}$	0.629	0.642	2.07	0.557	0.516	-7.36
$C_{18:0}$	5.548	6.792	22.42	4.909	5.458	11.18
$C_{20:0}$	0.431	0.438	1.62	0.381	0.352	-7.61
$C_{21:0}$	0.187	0.199	6.42	0.165	0.159	-3.64
Σ(Saturated)	37.690	40.524	7.52	33.347	32.563	-2.35
$C_{14:1}$	0.157	0.139	-11.46	0.139	0.112	-19.42
$C_{15:1}$	0.053	0.070	32.08	0.046	0.056	21.74
$C_{16:1\ \omega\text{-}7}$	6.397	6.441	0.69	5.660	5.176	-8.55
$C_{17:1}$	0.506	0.473	-6.52	0.448	0.380	-15.18
$C_{18:1\ \omega\text{-}9}$	10.581	12.709	20.11	9.362	10.213	9.09
$C_{20:1\ \omega\text{-}11+\ \omega\text{-}9}$	2.010	2.586	28.66	1.857	2.078	11.90
$C_{22:1\ \omega\text{-}11+\ \omega\text{-}9}$	0.369	0.334	-9.49	0.326	0.269	-17.48
Σ(Monounsaturated)	20.073	22.752	13.35	17.838	18.284	2.50
$C_{18:2\ \omega\text{-}6}$	42.532	47.300	11.21	37.633	38.000	0.98
$C_{18:3\ \omega\text{-}3}$	0.154	0.194	25.97	0.136	0.156	14.71
$C_{20:2\ \omega\text{-}6}$	0.747	0.888	18.88	0.661	0.713	7.87
$C_{20:3\ \omega\text{-}3}$	0.457	0.523	14.44	0.405	0.421	3.95
$C_{20:4\ \omega\text{-}3}$	0.297	0.381	28.28	0.263	0.306	16.35
$C_{20:5\ \omega\text{-}3}$	0.331	0.426	28.70	0.293	0.342	16.72
$C_{22:2}$	0.883	1.019	15.40	0.782	0.819	4.73
$C_{22:6\ \omega\text{-}3}$	0.190	0.203	6.84	0.168	0.163	-2.98
Σ(Polyunsaturated)	45.591	50.934	11.72	40.341	40.920	1.44
Total unsaturated	65.664	73.686	12.22	58.179	59.204	1.76
ω-3/ω-6	0.033	0.036	9.09	0.033	0.036	9.09
Biological Value*	1.74	1.82	4.60	1.74	1.82	4.60

*** Biological value means total unsaturated fatty acids / total saturated fatty acids.**

Total polyunsaturated fatty acids recorded about 40% and did not change as affected by grilling process. Subsequently, total unsaturated fatty acids reached 58.179% and 59.204% in raw and grilled Tilapia fish flesh, respectively. Biological value of Tilapia oil increased as affected by grilling process with increase of 4.6%.

ω-3/ω-6 ratio was very small and this indicted that Tilapia oil could not be considered a source of omega-3 fatty acids. However, *Al-Saghir et al.(2004)* observed that ω-3/ω-6 ratio remained constant after frying of Salmon fillets in olive oil.

Finally, a comparison between fatty acids composition of the previous studied fish oils should be in consideration. From results in Tables (2, 3 and

4), it easily could be concluded that palmitic ($C_{16:0}$) acid was the main saturated fatty acid in the three studied fish samples. It reached 23.877%, 21.359% and 22.194% in raw Sardine, Mullet and Tilapia, respectively. Palmitic acid remained constant in grilled Tilapia, but it decreased by 6.50% in grilled Sardine and increased by 4.82% in grilled Mullet. It could b noticed that stearic ($C_{18:0}$) acid recorded valuable content in raw Sardine and Tilapia (5.236% and 4.909%, respectively). Total saturated fatty acids in the three studied fish samples were more than 30%. These ratios decreased in Sardine and Tilapia and increased in Mullet as affected by grilling process.

$C_{16:1\ \omega\text{-}7}$ fatty acid was reported as the main monounsaturated fatty acids in raw Sardine and Mullet, where it reached 13.815% and 11.584%, respectively. While oleic acid was the main monoens in raw Tilapia (9.362%). Total monounsaturated fatty acids content recorded the values of 30.36%, 23.797% and 17.838% in raw Sardine, Mullet and Tilapia, respectively.

$C_{18:2\ \omega\text{-}6}$ linoleic acid was the main polyunsaturated fatty acid in the three fish samples. Linoleic acid content in raw Tilapia fish was the highest (37.633%). And subsequently, polyunsaturated fatty acids content in raw Tilapia were the highest (40.341%), while raw Sardine fish had the least content (14.86%). Grilling process caused an increase of polyunsaturated fatty acids content in all fish samples.

CONCLUSION

. From previous results, it could be reported that the most common Egyptian fish contained low contents of necessary fatty acids especially omega-3 fatty acids (EPA and DHA). This note may be due to the month of capture, the season and some environmental conditions. Also, grilling process affected on fatty acids composition of the most common Egyptian fish in different manner according to fish type and thickness. So, it is recommended to increase consumption of other types of fish which are rich in these fatty acids.

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تأثير عملية الشي التقليدية على القيمة الغذائية و تركيب الأحماض الدهنية في أكثر الأسماك المصرية انتشارا

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تم تنفيذ هذا البحث لدراسة تأثير عملية الشي التقليدية على القيمة الغذائية و تركيب الأحماض الدهنية في أكثر الأسماك المصرية انتشارا (البلطي ، البوري و السردين). و قد أظهرت النتائج إنخفاض كلاً من نسبة الرطوبة ، الرماد و الزيت في الأسماك نتيجة عملية الشي ، حيث انخفضت نسبة الزيت من ٢٢,١٤% إلى ١١,٤٠% (على أساس وزن جاف) في اسماك البوري. بينما ارتفعت نسبة البروتين الخام نتيجة عملية الشي من ٦٩,٠٤% إلى ٨٦,٧١% (على أساس وزن جاف) في أسماك البوري أيضاً. أما بالنسبة لتركيب الأحماض الدهنية ، انخفضت نسبة الأحماض الدهنية المشبعة بمقدار ٤,٢٥% و ٢,٣٥% لأسماك السردين و البلطي على الترتيب بينما ارتفعت هذه النسبة في أسماك البوري حيث وصلت نسبة الارتفاع نحو٦,٢٥%. كذلك انخفضت نسبة الأحماض الدهنية أحادية عدم التشبع في أسماك السردين و البوري حيث مثلت نسبة الانخفاض نحو ٣,٨٤% و ١١,٧٢% على الترتيب. أما عن نسبة الأحماض الدهنية عديدة عدم التشبع فقد ارتفعت نتيجة عملية الشي في جميع أنواع الأسماك بنسب متفاوتة. و لقد ارتفعت القيمة الحيوية لزيوت الأسماك في كلاً من السردين و البلطي حيث بلغت نسبة الارتفاع نحو ٩,٧٦% و ٤,٦% على الترتيب ، بينما انخفضت هذه النسبة في البوري حيث بلغت نحو ٩,٥٥%. هذا و قد أظهرت نتائج هذه الدراسة فقر في محتوى الأسماك المصرية الشائعة من الأحماض الدهنية عديدة عدم التشبع خاصةً الأوميجا-٣ (EPA and DHA) و بالتالي ننصح بزيادة استهلاك أنواع أخرى من الأسماك الغنية في هذه الأحماض الضرورية.

الكلمات الدالة: شي الأسماك – التركيب الكيماوي – القيمة الغذائية - تركيب الأحماض الدهنية.

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