Comparison of the Effects of Four Cooking Methods on Chemical Compositions and Fatty Acid Profiles of Iranian Silver Carp (Hypophthalmichthys molitrix) Fillets: A Study of Nutritional Quality Indices

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ABSTRACT

This study was performed to determine the influence of four cooking methods (frying, boiling, broiling and microwaving) on chemical composition, fatty acids profiles and also nutritional quality indices (NQI) of Iranian silver carp (Hypophthalmichthys molitrix) fillets. The decrease in the moisture content has been described as the most prominent change that makes the fat, protein, and ash contents increase significantly in cooked fish fillets. Boiling, Frying and broiling methods changed the fatty acid composition and NQIs of Iranian silver carp samples, but microwave cooking had no significant effect on NQIs. Frying and broiling methods caused significant reduction of the ω6 PUFA level, ω6/ω3 ratio and EPA+DHA. Consequently, they are not recommended for cooking from the view of thrombogenicity. As a result, for keeping the ω3 PUFA level, EPA+DHA and ∑ω3/ω6 ratio in Iranian silver carp, microwave cooking is recommended as the best cooking method.

INTRODUCTION

Fish has long been recognized as a valuable major source of food with excellent nutritional value, providing in lipids, high-quality proteins in essential amino acids, vitamins and wide variety of minerals [4, 29, 46] in the human diet. The most important nutritional value of fish consumption is due to the complex fatty acid profile [22, 32, 33]. Major groups of fatty acids based on the number of double bonds include saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) [23, 33]. The ω3 and ω6 polyunsaturated fatty acids are considered essential fatty acids, because they cannot be synthesized in the human body, they must be obtained through diet [28]. Polyunsaturated fatty acids ω-3 (PUFA ω-3) known to help in preventing heart disease and has anti-inflammatory and antithrombosis effects [12]. Also, Omega-3 fatty acids of fish oils appear mild antihypertensive effects [3], and can reduce some risk factors associated with arteriosclerosis [9] and cancer [19]. The ω-3 long-chain polyunsaturated the fatty acids (LC-PUFA) are mainly eicosapentaenoic acid (EPA, 20:5 ω-3) and docosahexaenoic acid (DHA, 22:6 ω-3). It is apparent that long-chain poly unsaturated fatty acids (LC-PUFAs) such as arachidonic acid (ARA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) have markedly different physiological properties and biological functions in comparison to the shorter chain PUFAs such as linoleic acid and α-linolenic acid [27].

Due to different effects of fatty acids on health, it is necessary to define the nutritional quality index (NQI) with consideration to the fatty acid profile and their biological functions. The nutritional quality index is estimated by several indices of fatty acid composition; the indices of atherogenicity (IA) and thrombogenicity (IT), according to Turan and coworkers [42], the hypcholesterolemic/hypercholesterolemic fatty acid ratio (HH) according to Testi and coworkers [40], EPA + DHA, PUFA/(SFA-stearic acid) according to Unusan [44], PUFA/SFA ratio according to Kalogeropoulos et al. [25] and Marques et al. [30], ∑ω3/ω6 PUFA ratios according to Marques et al. [30], and ultimately ARA/EPA and UFA/SFA ratios according to Larsen et al [27].
Fish is usually cooked before consumption with different methods. Using of heat during household cooking of foodstuffs contain a variety of processes, such as boiling, baking, roasting, frying, steaming, grilling, and microwave [6]. Cooking can improve or impair the food nutritional value due to chemical and physical reactions that occur when foods are heated. For example, digestibility is increased because of protein denaturation in food but the content of thermolabile compounds, fat-soluble vitamins or polyunsaturated fatty acids are often reduced [7]. The polyunsaturated fatty acids are more sensitive to oxidation during heating than their saturated analogues [23]. Usually, different cooking methods improve hygienic quality of the food by inactivation of pathogenic microorganisms and enhance digestibility and bio-availability of nutrient in the digestive tract [6].

Among the large groups of fish species which have been consumed in Iran, silver carp (Hypophthalmichthys molitrix) is one of the most important reared fish in the world [16] that has an excellent economic importance in the Caspian Sea and also high acceptability among northern cities [47, 48]. Physicochemical and sensory properties of silver carp (Hypophthalmichthys molitrix) fillets were evaluated after cooking with different methods [21]. Naseri and coworkers [34] were determined effect of different precooking methods (steaming, oven-baking and microwave-cooking) on chemical composition and lipid damage of silver carp. Buchova and Jezek [8] had a new look to the silver carp as a food fish. Zakipour Rahimabadi and Dad [47] were studied effects of frying by different frying oils on fatty acid profile of silver carp. Also, Naseri and coworkers [33] were investigated the effect of frying in different culinary fats on the fatty acid composition of silver carp. Also, Tothmarkus and Sasskiss [41] studied the effect of cooking on the fatty-acid composition of silver carp in cooked and deep fat fried fillets. The purpose of present investigation is to obtain information on any changes of some chemical compositions (protein, lipid, moisture, and ash) and the fatty acids profiles of Iranian silver carp (Hypophthalmichthys molitrix) fillets due to different cooking methods such as pan frying, boiling, broiling and microwaving, with special remarks concerning of nutritional quality indices including the content of PUFA/SFA, PUFA/(SFA-steaacid) and UFA/SFA ratios, ∑EPA+DHA, and ∑ω3/ω6 ratio changes.

**MATERIALS AND METHODS**

**Samples Preparation:**

Ten silver carps (n= 10, weight = 1000-1200 gr) were collected from a local market (Azadshahr, Iran) (Lat: 37.05° N; Lon: 55.10° E) and transported to laboratory in ice containing boxes with fish to ice ratio of 1:2 (w/w). Then, the fish were washed with tap water several times to remove adhering blood and slime, they were then prepared such as eviscerated, beheaded, removing backbone, skin, tail and fin yielding two fillets. At least they were randomly divided in to 5 lots, which were assigned to the three repetitions of each one of the 4 cooking methods (frying, boiling, broiling, and microwaving). The raw fillets group was used as a reference.

**Cooking Methods:**

Four common ways of cooking were used. The samples were cooked by frying, boiling, broiling, and microwave oven. The fish fillets were fired in sunflower oil (Ladan oil, Iran), in a frying pan. The temperature of oil during the frying process was 150°C for 14 min (7 min on each side). The broiling process was carried out after cooking with different methods [21]. Naseri and coworkers [34] were determined effect of different precooking methods (steaming, oven-baking and microwave-cooking) on chemical composition and lipid damage of silver carp. Buchova and Jezek [8] had a new look to the silver carp as a food fish. Zakipour Rahimabadi and Dad [47] were studied effects of frying by different frying oils on fatty acid profile of silver carp. Also, Naseri and coworkers [33] were investigated the effect of frying in different culinary fats on the fatty acid composition of silver carp. Also, Tothmarkus and Sasskiss [41] studied the effect of cooking on the fatty-acid composition of silver carp in cooked and deep fat fried fillets. The purpose of present investigation is to obtain information on any changes of some chemical compositions (protein, lipid, moisture, and ash) and the fatty acids profiles of Iranian silver carp (Hypophthalmichthys molitrix) fillets due to different cooking methods such as pan frying, boiling, broiling and microwaving, with special remarks concerning of nutritional quality indices including the content of PUFA/SFA, PUFA/(SFA-steaacid) and UFA/SFA ratios, ∑EPA+DHA, and ∑ω3/ω6 ratio changes.

**Chemical Composition and Fatty Acids Analysis:**

The moisture content was determined by means of oven at 103°C [2]. The amount of ash was measured by drying the sample in an electrical kiln at 550°C [2]. The amount of crude protein was determined by Kjeldahl Method [2] and crude fat was measured using Suxele method [2]. Lipid was extracted by the method of Bligh and Dyer [5] and used for lipid quantification and for determination of the fatty acid profile. Fatty acid methyl esters (FAMEs) were determined following the methodology described by Meteal et al. [31]. The fatty acid compositions of fish flesh were determined using a gas chromatograph (Unicam-4600) equipped with a Flame Ionization Detector (FID) and a 30 mm long × 0.25 mm internal diameter capillary column PB×70. The oven temperature was 160°C for 6 min, followed by an increase to 180°C at a rate of 20°C/min and held for 9 min at 180°C and followed by an increase to 200°C at rate 20°C/min then held for 5 min at 200°C. The injection split ratio was 1:10. The temperatures of the injection port and detector were 250°C and 280°C respectively. Helium was used as gas carrier. The fatty acids were expressed as percentage of the total fatty acid content. The standard fatty acids were analyzed in triplicate for each sample and were reported as g/100 g of dry weight.
Statistical Analysis:
Data normality was assessed through Kolmogorov-Smirnov method. The obtained data were analyzed via one-way ANOVA and Duncan Post hoc (p≤0.05). Also, SPSS 20 Software was adopted to analyze the data.

RESULTS AND DISCUSSION

Silver carp is an extensively cultured species. Aquaculture production of silver carp is the highest of any fish species in the world that has an annual global production of nearly 4.2 million metric tons [34]. Fish biometry showed the average length and weight muscles were 37±1 cm and 1100±72 g.

Chemical Compositions:

Results of proximate (protein, lipid, ash, and moisture) are shown in Table 1. The moisture content in raw, microwaved, boiled, broiled and fried fillets were obtained 68.51±6.91%, 72.86 ± 5.96%, 75.49± 4.36%, 65.23±5.7% and 50.77± 5.98%, respectively. The results of moisture content were showed that there was no significant different in raw, microwaved, boiled and broiled fillets, exception fried fillets (Table 1). The moisture content of the fish fillets were decreased after broiling and frying, while were increased after boiling and microwaving process (Table 1).The moisture changes were obtained in the present study were agreement to other studies of the authors [21, 35-37, 41].

Fat content was found to be 4.35±1.20% in raw fish fillets. The highest fat content was related to the fried fish fillets (10.26±1.68%), while boiled fillets had the lowest (1.72±0.19%) (Table 1). These results were in agreement with results of [41]. Boiled fillets contained a higher level of moisture compared to raw and cooked samples; and fried fillets had the lowest rate of moisture between the cooked ones. The moisture contents of the fish fillets were inversely related to the total lipid content. The increase of the fat content in the fried fillets may be explained by two mechanisms, namely the loss of water during frying and the absorption of culinary fat [13, 18, 21, 38]. In boiling process, boiling water can effect on exiting fat content of meat fish and decrease that. These results were in agreement with results of Castrillon et al. [11], Sanchez-Muniz et al. [38], Zakipour Rahimabadi and Dad [47], Naseri [33] and Hakimeh et al. [21].

The results of protein content were showed that there was no significant different in raw, microwaved, boiled, and broiled; exception fried fillets (Table 1). Protein content was recorded to be 20.75±2.89% in raw samples; and fried fillets had the lowest rate of moisture between the cooked ones. The moisture contents of the fish fillets were decreased after broiling and frying, while were increased after boiling and microwaving process (Table 1). The moisture changes were obtained in the present study were agreement to other studies of the authors [21].

The ash content was increased after frying, boiling, and broiling; exception microwave-cooked fillets (Table 1). Broil-cooked fillets had the highest ash content (3.52±0.75%), while the lowest ash content was related to raw and microwave-cooked fillets with 1.85±0.59% and 1.84±0.46%, respectively (Table 1). The values obtained in this study were agreement to other studies of the authors [21].

Generally, Gokoglu et al., [20] reported that the increase in protein, fat and ash contents could be explained by the reduction in moisture.

Table 1: Proximate composition of raw and cooked fish fillets.

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>Raw</th>
<th>Microwaved</th>
<th>Boiled</th>
<th>Broiled</th>
<th>Fried</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>68.51±6.91%</td>
<td>72.86±5.96%</td>
<td>75.49±4.36%</td>
<td>65.23±5.7%</td>
<td>50.77±5.98%</td>
</tr>
<tr>
<td>Fat</td>
<td>4.35±1.20%</td>
<td>3.09±0.64%</td>
<td>1.72±0.19%</td>
<td>2.79±0.38%</td>
<td>10.26±1.68%</td>
</tr>
<tr>
<td>Protein</td>
<td>20.75±2.89%</td>
<td>18.24±2.02%</td>
<td>17.52±3.34%</td>
<td>23.48±2.11%</td>
<td>31.47±2.35%</td>
</tr>
<tr>
<td>Ash</td>
<td>1.85±0.59%</td>
<td>1.84±0.46%</td>
<td>1.99±0.15%</td>
<td>3.52±0.75%</td>
<td>2.51±0.32%</td>
</tr>
</tbody>
</table>

Results are means ± standard deviation of triplicates.
Means within the same column having different superscripts are significantly different (p < 0.05).

Fatty Acid Composition:

The most important fatty acid profile of raw, microwaved, boiled, broiled and fried samples of silver carp fish are shown in Table 2. Fatty acids compositions respond differently to different cooking methods.

The 16 fatty acids were detected in raw samples. Raw silver carp fillets were showed considerable amounts of palmitic (21.37±1.12%), stearic (10.49±0.66%), palmitoleic (2.57±0.09%), oleic (21.37±1.12%), linoleic (3.80±0.29%), linolenic (0.96±0.83%), arachidonic (9.83±0.42%), eicosapentaenoic (6.45±0.65%) and docosahexaenoic (8.73±1.63%) acids (Table 2). These findings were in agreement with those obtained by Vujkovic et al. (1999) and Zakipour Rahimabadi and Dad (2012). Content of oleic and linoleic acids were increased in all methods in comparison with raw samples. Oleic acid was increased in microwaved and boiled fillets than raw samples from 13.21% to 22.53 and 21.50%, respectively (Table 2). Higher content of oleic acid was found in fried (by sunflower oil) and broiled samples, 2.138 and 2.076 times higher of raw samples, respectively (Table 2). In boiled and fried samples, the increase was happened in the content of linoleic acid (7.284 and 15.437 times higher, respectively) in comparison with raw samples (Table 2). Changes in fried
samples were different due to higher increment in the content of linoleic and oleic acids of sunflower oil consumed in comparison with raw samples (Table 3). Sunflower oil is the most popular frying oil in Iran and it is a good source of linoleic and oleic acids. Due to oil absorption during frying, the high level linoleic and oleic acids in the fried fish was attributed to the fatty acid composition of sunflower oil. Content of palmitic, eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids were also decreased in all of them than raw fillet (Table 2). These findings were in agreement with other obtained by Zakipour Rahimabadi and Dad [47]. Boiling and microwave had no significant effect on the arachidonic acid content, while frying and broiling caused significant reduction. Reduction of arachidonic acid could be explained by high susceptibility of double bond fatty acids [14]. Palmitoleic acid was reduced in boiled, broiled and fried samples, but did not have significant change in microwaved fillets (Table 2). Content of stearic acid was shown to increase in microwaved and boiled fillets instead to decrease by broiling and frying process (Table 2).

Table 2: Fatty acid composition of raw and cooked fillets.

<table>
<thead>
<tr>
<th>Fatty acids</th>
<th>SFA</th>
<th>MUFA</th>
<th>PUFA</th>
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</thead>
<tbody>
<tr>
<td>C14:0</td>
<td>0.56±0.48%</td>
<td>1.81±2.32%</td>
<td>0.26±0.22%</td>
</tr>
<tr>
<td>C15:0</td>
<td>0.20±0.17%</td>
<td>0.11±0.20%</td>
<td>0.07±0.12%</td>
</tr>
<tr>
<td>C16:0</td>
<td>21.37±1.12%</td>
<td>21.90±4.64%</td>
<td>19.77±2.72%</td>
</tr>
<tr>
<td>C17:0</td>
<td>1.16±0.01%</td>
<td>0.82±0.72%</td>
<td>1.41±0.94%</td>
</tr>
<tr>
<td>C18:0</td>
<td>10.49±0.66%</td>
<td>11.49±0.88%</td>
<td>16.93±1.41%</td>
</tr>
<tr>
<td>C20:0</td>
<td>0.0±0%</td>
<td>0.21±0.47%</td>
<td>0.5±0.47%</td>
</tr>
<tr>
<td>C24:0</td>
<td>0.0±0%</td>
<td>0.22±0.23%</td>
<td>0.48±0.42%</td>
</tr>
<tr>
<td>C14:1</td>
<td>0±0%</td>
<td>0.0±0.15%</td>
<td>0.0±0%</td>
</tr>
<tr>
<td>C15:1</td>
<td>0±0%</td>
<td>0.07±0.12%</td>
<td>0.05±0.04%</td>
</tr>
<tr>
<td>C16:1 ω9</td>
<td>2.57±0.00%</td>
<td>2.16±0.59%</td>
<td>1.29±0.25%</td>
</tr>
<tr>
<td>C17:1</td>
<td>0.32±0.27%</td>
<td>0.42±0.37%</td>
<td>0.44±0.38%</td>
</tr>
<tr>
<td>C18:1 ω9 trans</td>
<td>0.49±0.42%</td>
<td>0.41±0.4%</td>
<td>0.21±0.37%</td>
</tr>
<tr>
<td>C18:1 ω7 cis</td>
<td>12.31±1.44%</td>
<td>22.53±2.30%</td>
<td>21.50±3.49%</td>
</tr>
<tr>
<td>C22:1 ω5</td>
<td>0±0%</td>
<td>1.09±0.12%</td>
<td>0.64±0.55%</td>
</tr>
<tr>
<td>C24:1 ω9</td>
<td>3.54±0.11%</td>
<td>2.09±0.97%</td>
<td>3.32±1.45%</td>
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Table 3: Fatty acid composition of sunflower oil.

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<tbody>
<tr>
<td>Value</td>
<td>6.12</td>
<td>3.36</td>
<td>28.20</td>
<td>60.16</td>
<td>10.07</td>
<td>28.29</td>
<td>61.40</td>
<td>0.22</td>
<td>61.18</td>
<td>0.004</td>
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</tbody>
</table>

Fatty acid contents presented in raw fish (with 4.35% total fat) followed a relative pattern with SFA > PUFA > MUFA (Table 4). SFA was the most abundant fatty acid (33.78 % of total fatty acids) followed by PUFA (30.15 % of total fatty acids) and MUFA (20.13% of total fatty acids) (Table 4). The most abundant fatty acids in PUFA of raw samples were AA (9.83 % of total fatty acids), DHA (8.73 % of total fatty acids) and EPA (6.45% of total fatty acids), followed by C20:4, C20:5 and C22:6 (Table 2). Also, among the unsaturated fatty acids (PUFA), ω3 fatty acid contents (16.14% of total fatty acids) were higher than that of ω6 fatty acids (14.01% of total fatty acids) (Table 4). In this investigation, the amount obtained of MUFA, EPA and DHA in silver carp were lower than the mean values reported by Zakipour Rahimabadi and Dad [47]. These differences may depend on nutrition, sex, season, and environmental conditions.

This arrangement was changed by using of different cooking method. All of cooking methods had significant effect on the MUFA content (Table 4). Boiling and microwave cooking had no significant effect on the total SFA and PUFA content. But, boiling and frying caused significant reduction on the total SFA content and important increase on the total PUFA content (Table 4). The significant increase of oleic and linoleic acids contents (as a MUFA and PUFA, respectively) in fried and broiled fillets (Table 2) were caused to considerable reduce SFA values. Present results were showed that the major fatty acids of frying oil (oleic (28.20%) and
linoleic (60.16%) acids contents) were observed by fried slices which caused to heterogeneous changes in the content of other fatty acids (Table 3 and 4).

| Table 4: Nutritional quality indices (NQI) raw and cooked fish fillets. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  | Raw             | Microwaved      | Boiled          | Fried           |
| ∑SFA             | 33.78±1.22 a    | 36.56±1.01 ab   | 39.35±1.18 ab   | 21.03±1.77 a    | 10.60±0.66 a    |
| ∑MUFA            | 20.13±1.31 a    | 28.77±1.16 a    | 27.40±0.37 a    | 32.5±0.46 a     | 28.54±1.59 a    |
| ∑PUFA            | 30.15±1.96 a    | 30.57±2.89 a    | 28.69±1.59 a    | 46.04±2.45 a    | 61.39±2.08 a    |
| ∑MUFA/PUFA       | 50.28±1.47 a    | 59.34±1.97 a    | 56.09±2.23 a    | 78.54±0.89 a    | 89.93±1.20 a    |
| ω3                | 16.40±1.32 a    | 14.53±1.92 a    | 11.14±0.57 a    | 12.51±0.67 a    | 2.10±1.22 a     |
| ω6                | 14.01±0.99 a    | 16.04±0.85 a    | 17.55±0.63 a    | 33.33±1.07 a    | 59.29±0.21 a    |
| ω3/(ω6+ω9)       | 15.18±1.98 a    | 11.51±1.30 a    | 9.25±0.16 a     | 10.97±0.37 a    | 0.35±0.08 a     |
| PUFA/SFA         | 0.89±0.1 a      | 0.83±0.09 a     | 0.72±0.18 a     | 2.18±0.72 a     | 5.79±0.02 a     |
| PUFA/(SFA-oleic acid) | 1.29±0.13 ab  | 1.21±0.08 ab    | 1.27±0.38 ab    | 3.26±0.9 ab     | 8.64±1.1 a      |
| UFA/SFA          | 1.48±0.52 b     | 1.62±0.45 b     | 1.42±0.10 b     | 3.73±0.91 b     | 8.48±0.06 b     |
| ∑ω3/∑ω6          | 1.35±0.85 b     | 2.29±0.07 b     | 1.05±0.16 b     | 2.20±0.23 b     | 1.69±0.07 b     |
| C22:6/C16:0       | 1.15±0.25 b     | 0.9±0.26 bc     | 0.63±0.35 bc    | 0.37±0.03 bc    | 0.03±0.002 bc   |
| C22:6+C20:5/C16:0 | 0.71±0.05 a     | 0.52±0.09 a     | 0.46±0.03 a     | 0.89±0.1 a      | 0.05±0.01 a     |

Results are means ± standard deviation of triplicates.

Means within the same column having different superscripts are significantly different (p < 0.05).

Apart from frying that led to a significant decrease in ω3, none of the other cooking methods had a significant effect on ω3. Unusan [44] showed that baking and microwave cooking had no significant effect on the ω3 fatty acid content and Weber et al. [46] reported that frying in hydrogenated vegetable oil caused reduction in the ω3 content. Domiszewski and coworkers [15] have reported that boiling (without salt) had no effect on the total ω3 content and other cooking methods (boiling with salt, microwave cooking and frying) caused significant reduction. It seems that oil absorption by fish is the most important factor reducing the total ω3 content during frying. The effect of other cooking methods (boiling, broiling and microwave cooking) on the reduction of ω3 content depends on the fatty acid composition and their sensitivity to oxidation. The most abundant fatty acids in ω3 content of raw samples were DHA and EPA (Table 2). These results were in agreement with results of Tothmarkus and Sasskiss [41]. The DHA/EPA ratio in raw fish was 1.38. Testi et al. [40] defined PI (peroxidisability index) for evaluating the relationship of fatty acid composition and its sensitivity to oxidation as follows:

PI=(0.025×monoenes)+(1×dienes)+(2×triene)+(4×tetraenes)+(6×pentaenes)+(8×hexaenes)

A high level of PI shows a higher sensitivity of fatty acids to oxidation. The PI index value of 154.46 was obtained in this study. PI values for Weber et al. [46], Hosseini [23] and Unusan [44] studies were 74.55, 170.80 and 133.94, respectively. Our fish samples were more sensitive to oxidation during cooking. Consequently, the suggested reason for the mild effect of cooking on the total ω3 content reported in previous studies may be related to the lower PI index of the samples [44, 46]. Broiled and fried samples were showed a more increase in ω3 fatty acids content than the microwaved and boiled samples. Using of sunflower oil for frying caused to great increase in the content of ω3 fatty acids (Table 3). That increased the content of C18:2 fatty acid and subsequently the content of ω6 PUFAs (Table 3). The results were in accordance with the reports of other researchers [44, 46]. Weber et al. [46] showed that frying in soy oil caused a higher increase of ω6 content in comparison with hydrogenated vegetable oil and canola oil due to the higher content of ω6 in soy oil. Similar results were found in frying of sunflower oil [10, 26], due to oil absorption in frying process that in turn dilutes the concentration of other fatty acids. As the initial lipid content of fish [1] and method of frying [26] were determinable in fatty acids composition changes, special care must be done in selecting the frying oil with regard to health benefits of ∑ω3/∑ω6 ratio. It was been reported that vegetable oils rich in ω6 PUFAs should be avoided in pan and deep-fat frying [1].

Nutritional Quality Indices (NQI):

PUFA/SFA, PUFA/(SFA-oleic acid) and UFA/SFA:

The greatest increase in PUFA/SFA, PUFA/(SFA-oleic acid) and UFA/SFA ratios was observed in fried samples, due to absorption of oil by the fish samples (Table 4). The evidence indicates that the effect of SFA on raising low-density lipoprotein cholesterol (LDLC) depends on the chain length, thus C14:0 and C16:0 are the most active while longer lengths have little or no effect on serum cholesterol levels. Of the saturated fatty acids (SFA), only those with a chain length of 14 or 16 carbon atoms have a cholesterol-raising effect and are therefore atherogenic. SFAs with a chain length of 14, 16 or 18 carbon atoms have been suggested to be thrombogenic [17]. On the other hand, MUFA has a beneficial effect on health by raising high-density lipoprotein cholesterol (HDLC) [17, 25].
An increase in the ω3/ω6 ratio in raw sample was around 1.15 (Table 4). This ratio ranged from 0.03 to 0.9 in different cooked fish species (Table 4). Boiling and microwave cooking had no significant effect on the ω3/ω6 ratio. Broiled and fried samples were showed a more decrease (than microwaved and boiled fillets) in ω3 fatty acids content and increase in ω6 fatty acids content, which caused to reduce in ω3/ω6 fatty acids ratio to 0.37 and 0.03, respectively (Table 4). Using of sunflower oil for frying caused to great increase in ω6 fatty acids (Table 3) and decreased the ratio of ω3/ω6 fatty acids. Excessive amounts of omega-6 polyunsaturated fatty acids (PUFA) and a very low ∑ω3/ω6 ratio, as was found in today’s Western and Eastern diets, promote the pathogenesis of many diseases, including cardiovascular disease, cancer, and inflammatory and autoimmune diseases, whereas increased levels of omega-3 PUFA (a high omega-3/omega-6 ratio) exert suppressive effects [39].

EPA + DHA:
EPA and DHA are long chain ω3 fatty acids that are precursors of hormones known as eicosanoids which play important roles in biological processes within the body such as brain and Retina-DHA is a building block of tissue in the brain and retina of the eye. According to the American Heart Association, about 1.0 g/day of EPA+DHA, or two servings of fatty fish per week reduces the risk of death from coronary heart disease [24]. Thus, "EPA + DHA" is one of the most important nutritional quality indexes. In this manuscript, EPA+DHA values in all methods were reduced (Table 4). However, frying was caused the highest reduction and microwave cooking had the lowest reduction among other methods. These results were in agreement with results of Tothmarkus and Sasskiss [41].

Conclusion:
All cooking methods evaluated in this study, changed chemical composition and the fatty acid profile of Iranian silver carp slices. The decrease in the moisture content has been described as the most prominent change that makes the fat, protein, and ash contents increase significantly in cooked fish fillets. The SFA contents increased in the boiled and microwave-cooked fillets, while showed decrease in fried and broil-cooked fillets. The MUFA increased in all evaluated samples. The PUFA increased in fried and broil-cooked fillets, but there was no significant difference in the two other cooking methods (P>0.05). The ω3 PUFA level, ω3/ω6 ratio and EPA+DHA are the best nutritional quality indices in fish. Boiling, Frying and broiling methods changed the fatty acid composition and NQIs of Iranian silver carp samples, but microwave cooking had no significant effect on NQIs. Frying and broiling methods caused significant reduction of the ω3 PUFA level, ω3/ω6 ratio and EPA+DHA. Consequently, they are not recommended for cooking from the view of thrombogenicity. As a result, for keeping the ω3 PUFA level, EPA+DHA and ω3/ω6 ratio in Iranian silver carp, microwave cooking is recommended as the best cooking method.

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