Semra Kaçar*, Mehmet Başhan

Comparison of lipid contents and fatty acid profiles of freshwater fish from the Atatürk Dam Lake

Atatürk Baraj Gölü’ndeki tatlısu balıklarının lipid içeriği ve yağ asidi profilinin karşılaştırılması

Abstract: Objective: The objective of the study was to examine the lipid levels, fatty acid profiles (especially EPA and DHA which play an important role in the prevention of a wide variety disorders such as; coronary heart disease, hypertension, rheumatoid arthritis, breast and colon cancer, Alzheimer disease, inflammation and autoimmune disorders) and n-3/n-6 ratio of some freshwater fish in Atatürk Dam Lake.

Methods: Samples of 12 fish species from the Atatürk Dam Lake (Turkey) were investigated for their fat content and fatty acid composition (Aspius vorax, Carasobarbus luteus, Carassius gibelio, Liza abu, Acanthobrama marmid, Barbus xanthopterus, Cyprinion macrostomum, Carassius auratus, Calcalburnus mossulensis, Capoeta trutta, Mastacembelus simack, Chondrostoma regium). Total lipids were extracted with 10 ml of chloroform-methanol (2/1v/v). Samples containing muscle lipid were transesterified with acidified methanol. The fatty acid methyl esters were extracted with hexane. Fatty acids were detected by gas chromatography (GC).

Results: The lipid content of species ranged from 0.78% to 2.51%. The highest lipid content was found in female C. trutta (2.51%). The major SFAs were myristic acid (C14:0), palmitic acid (C16:0) and stearic acid (C18:0). Oleic acid (C18:1 n-9) and palmitoleic acid (C16:1 n-7) were the prominent MUFA. The dominant PUFAs were linoleic acid (LA, C18:2 n-6), linolenic acid (ALA, C18:3 n-3), arachidonic acid (AA, C20:4 n-6), eicosapentaenoic acid (EPA, C20:5 n-3) and docosahexaenoic acid (DHA, C22:6 n-3). The ratio of n-3/n-6 PUFAs ranged from 1.22 to 4.71.

Conclusion: In this study, the fatty acid composition varied between different species In addition, the highest n-3/n-6 ratios were observed in female C. trutta, C. mossulensis, C. regium and A. vorax. Therefore, these species are economically important fish considering n-3 fatty acids and n-3/n-6 ratios.

Keywords: Atatürk Dam Lake, freshwater fish, fatty acid

*Corresponding author: Semra Kaçar: Mardin Artuklu University, Department of Nutrition and Dietetics, School of Health, 47100 Mardin, Turkey, e-mail: semrakacar21@gmail.com

Mehmet Başhan: Dicle University, Faculty of Science, Department of Biology, 21280 Diyarbakır, Turkey, e-mail: mehmetbashan@gmail.com

DOI 10.1515/tjb-2016-0025
Received June 25, 2015; accepted January 30, 2016
n-9) ve palmitoleik asit (C16:1 n-7) belirgin MUFA'larıydı. Baskın PUFA'lar linoleik asit (LA, C18:2 n-6), linolenik asit (ALA, C18:3 n-3), arakidonik asit (AA, C20:4 n-6), eikosapentaenoik asit (EPA, C20:5 n-3) ve dokosahexaenik asit (DHA, C22:6 n-3)'lerdi. N-3/n6 PUFA'lar 1.22'den 4.71'e deşisti.


Anahtar Kelimeler: Atatürk Baraj Gölü, tatlısu balığı, yağ asidi

Introduction

Atatürk Dam Lake on the Euphrates River (Turkey) is the biggest reservoir in Turkey and has a high fishing potential. About 28 fish species and subspecies belonging to eight families living in the Euphrates River and its dam lakes have been recorded [1]. A. vorax (female), C. luteus (male), C. gibelio (female), L. abu (female), A. marmid (female), B. xanthopterus (female), C. macrostomum (female), C. auratus (male), C. mossulensis (female), C. trutta (female), M. simack (female) and C. regium (female) have economic value in the reservoir. Freshwater fishes are not only a major source of protein but they also contain nutritionally valuable lipids. Fish oils are currently under intense scientific investigation because of the numerous health benefits attributed to them. Information concerning the chemical and fatty acid composition of freshwater fishes is valuable to nutritionists who are interested in finding sources of low-fat, high protein foods, with desirable fatty acid compositions.

Fish oils are good sources of unsaturated omega-3 fatty acids, such as EPA, DHA and ALA [2,3]. Studies have shown that freshwater fish have a high capacity for the transformation of C18 essential fatty acids (EFAs); C18:3 n-3 and C18:2 n-6 to C20:5 n-3, C22:6 n-3 and C20:4 n-6 and thus may be a fine source of such acids to a consumer [4]. These fatty acids have been demonstrated to be very important for human health. EPA and DHA cannot be synthesised in the human body and thus need to be supplemented through dietary intake [5]. DHA and EPA provide health benefits by lowering serum triacylglycerol levels, increasing membrane fluidity, and reducing thrombosis [6]. Many studies have demonstrated that consumption of fish oil rich in n-3 PUFA has beneficial effects on coronary heart disease [7], hypertension [8], rheumatoid arthritis [9], breast and colon cancer [10], Alzheimer disease [11], inflammation and autoimmune disorders [12]. N-3 PUFAs play a vital role in the development and function of the nervous system, photoreception and the reproductive system [13,14]. These fatty acids are the usual precursors of the synthesis of eicosanoids, including prostaglandins and leukotriens. Eicosanoids derived from AA have negative cardiovascular effects, such as vasoconstrictions and platelet aggregation, while the reverse is true for EPA, it has positive effects, such vasodilation and antiaggregation. The consumption of AA in diets must be reduced [15].

The aim of this study was to determine the lipid levels, fatty acid profiles and n-3/n-6 ratio of some freshwater fish in Atatürk Dam Lake.

Materials and Methods

Samples

Wild fish species were caught with casting nets from Dam Lake in November 2008. The geographic co-ordinates of the study area were 37° 47′ 13.58′′ North and 38° 39′ 19.84′′ East (Kahta). The fish samples were immediately transported to the laboratory where morphometric measurements involving wet weight and length of each fish were carried out (Table 1). Fish sex was determined by their gonad. Analyses were performed in triplicate for each fish. From each specimen, an edible portion of the dorsal muscle between the dorsal fin and head was excised. This section was then skinned, deboned, and the muscle trimmed off. Three 1 g replicates were taken of each sample and stored in deep freeze at −20°C until analyses.

Lipid extraction and transmethylation of fatty acids

The muscle was homogenized in a blender. Lipids were extracted from homogenised muscle, using the method described by Folch et al. [16]. In this method, chloroform-methanol was used at the ratio of 2/1(v/v). To prevent autoxidation, 50 µL of 2% butylated hydroxytoluene was added to all samples. The amount of lipid was determined gravimetrically. Samples containing muscle lipid were transterified with acidified methanol [17]. The fatty acid methyl esters (FAMEs) were extracted with hexane.
Gas chromatography analyses

FAMEs were separated and quantified by capillary GC using a Hewlett Packard (Wilmington, DE) GC (model 6890), a BPX-70 capillary column (30 m x 320 μm (i.d) x 0.250 μm film thickness and Bonded 70% cyanopropyl) (J & W Scientific, Folsom, CA), a flame ionization detector (FID) and Hewlett-Packard ChemStation software. The injection port and the detector temperatures were 270°C and 280°C, respectively. The split ratio was 1:20. The flow rates of compressed air and hydrogen were 300 ml/min, 30 ml/min, respectively. Helium was the carrier gas (1.0 ml/min). The oven temperature was programmed at initial temperature of 130°C and was held for 1 min, then increased at a rate of 6.5°C/min to 170°C, then increased at a rate of 2.75°C/min to a 215°C was held for 12 min., then again increased at a rate of 40°C/min to 230°C, was held for 3 min. total analysis time was 38.8 min. Fatty acid levels and spectra of FAMEs were obtained with Hewlett-Packard 3365 ChemStation computer program. FAMEs’ existence and retention times were determined by comparing the spectra of authentic standards (Sigma-Aldrich Chemicals). Individual FAMEs were identified by comparing them with the chromatographic behaviours of authentic standards. Results were expressed as FID response area relative percentages. The amount of fatty acids was given as a percentage.

Statistical analysis

Statistical analyses were done with SPSS 15.0. All analytical determinations were performed in triplicate and the mean values were reported. The percentages of fatty acids were tested by analysis of variance (ANOVA) and comparisons between means were performed using Tukey’s test. Differences between means were considered to be significant at p<0.05.

Results and Discussion

Fat content

The lipid content of species ranged from 0.78% to 2.51% (Table 1). The highest lipid content was found in female C. trutta (2.51%) and the lowest was found in male C. luteus (0.78%).

The lipid content and fatty acid profile of fish vary between and with species even in dark and white muscle, which are affected by many factors such as the temperature, salinity, season, size, age, species habitat, life stage, and the type and abundance of food, especially whether a species is herbivorous, omnivorous or carnivorous [18,19].

Fish can be grouped into four categories according to their fat content: lean fish (fat less than 2%), low fat fish (fat 2–4%), medium fat fish (fat 4–8%) and high fat fish (fat more than 8% by weight) [20]. Of the 12 fish species investigated, ten were considered to be lean (A. vorax, (female) C. luteus (male), C. gibelio (female), L. abu (female), B. xanthopterus (female), C. macrostomum (female), C. auratus (male), C. mossulensis (female), C. regium (female), M. simack (female), having fat content of less than 2%, two species were considered to be low fat fish (A. marmid (female), C. trutta (female) having fat content of 2–4% (Table 1). Similar results were found by Ackman et al., [21] and Rasoarahona et al., [22] for some freshwater fish.

In this study, the low lipid contents in the fish species are probably due to absence in their natural food.
<table>
<thead>
<tr>
<th>Fatty acids</th>
<th>Aspius vorax</th>
<th>Carassius gibelio</th>
<th>Liza abu</th>
<th>Acanthobrama marmid</th>
<th>Barbus xanthopterus</th>
<th>Cyprinoid macrostomum</th>
<th>Carassius auratus</th>
<th>Calcarus mossulensis</th>
<th>Capoeta simack</th>
</tr>
</thead>
<tbody>
<tr>
<td>C12:0</td>
<td>0.03±0.01**</td>
<td>–</td>
<td>0.11±0.02b</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>C13:0</td>
<td>0.12±0.03a</td>
<td>–</td>
<td>0.11±0.01a</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>C14:0</td>
<td>3.26±0.38a</td>
<td>1.69±0.21b</td>
<td>2.05±0.27a</td>
<td>2.57±0.25a</td>
<td>2.87±0.33a</td>
<td>2.75±0.23a</td>
<td>2.02±0.16b</td>
<td>1.33±0.56a</td>
<td>2.57±0.22a</td>
</tr>
<tr>
<td>C15:0</td>
<td>0.60±0.18a</td>
<td>0.55±0.15a</td>
<td>1.23±0.28a</td>
<td>0.48±0.17a</td>
<td>0.62±0.10a</td>
<td>0.92±0.08a</td>
<td>1.07±0.63b</td>
<td>1.17±0.67b</td>
<td>0.61±0.23a</td>
</tr>
<tr>
<td>C16:0</td>
<td>18.66±1.04a</td>
<td>21.66±1.18a</td>
<td>17.71±2.56</td>
<td>23.72±2.76a</td>
<td>18.38±2.21</td>
<td>23.68±2.56a</td>
<td>27.79±1.98b</td>
<td>17.12±2.21</td>
<td>18.50±2.66</td>
</tr>
<tr>
<td>C17:0</td>
<td>1.01±0.63a</td>
<td>0.86±0.24b</td>
<td>0.78±0.33a</td>
<td>0.86±0.12a</td>
<td>0.84±0.20a</td>
<td>0.53±0.35a</td>
<td>0.97±0.01b</td>
<td>0.78±0.42b</td>
<td>0.51±0.13c</td>
</tr>
<tr>
<td>C18:0</td>
<td>4.94±1.02a</td>
<td>5.03±0.29a</td>
<td>6.57±1.06</td>
<td>6.19±1.23a</td>
<td>4.03±0.65a</td>
<td>5.29±1.03a</td>
<td>6.66±1.70b</td>
<td>7.34±1.09b</td>
<td>3.94±0.04c</td>
</tr>
<tr>
<td>∑SFA***</td>
<td>28.62±2.25a</td>
<td>29.79±2.98a</td>
<td>28.56±1.86</td>
<td>33.82±3.22</td>
<td>26.74±1.90</td>
<td>33.17±2.34</td>
<td>38.51±3.88b</td>
<td>27.74±1.56</td>
<td>26.13±2.33</td>
</tr>
<tr>
<td>C16:1 n-7</td>
<td>13.20±1.07a</td>
<td>6.93±1.39a</td>
<td>6.09±1.17</td>
<td>7.20±0.26</td>
<td>11.50±2.80</td>
<td>9.98±1.54a</td>
<td>5.05±0.09a</td>
<td>4.61±0.23</td>
<td>8.02±0.38a</td>
</tr>
<tr>
<td>C18:1 n-9</td>
<td>29.32±1.19a</td>
<td>25.28±2.33a</td>
<td>21.24±2.56</td>
<td>22.24±1.43</td>
<td>26.83±1.55</td>
<td>22.30±2.54</td>
<td>27.94±1.02a</td>
<td>17.12±1.90</td>
<td>22.96±2.03</td>
</tr>
<tr>
<td>C20:1 n-9</td>
<td>1.32±0.25a</td>
<td>4.33±1.09a</td>
<td>2.79±1.12</td>
<td>0.86±0.34</td>
<td>1.71±0.45</td>
<td>1.51±0.29</td>
<td>3.26±0.04a</td>
<td>2.14±1.25</td>
<td>0.87±0.39</td>
</tr>
<tr>
<td>∑MUFA***</td>
<td>43.84±3.47a</td>
<td>36.54±2.44a</td>
<td>30.12±2.98</td>
<td>30.30±2.34</td>
<td>40.04±3.85</td>
<td>33.79±2.09</td>
<td>36.25±2.66b</td>
<td>23.87±3.05</td>
<td>40.74±3.44</td>
</tr>
<tr>
<td>C18:2 n-6</td>
<td>3.56±0.56a</td>
<td>4.63±0.66a</td>
<td>10.18±2.04</td>
<td>3.08±0.08</td>
<td>3.86±0.15</td>
<td>2.39±0.37</td>
<td>4.72±1.34a</td>
<td>8.58±0.43</td>
<td>3.50±1.87c</td>
</tr>
<tr>
<td>C18:3 n-3</td>
<td>4.16±1.33a</td>
<td>5.68±1.10a</td>
<td>2.85±0.06</td>
<td>2.09±0.01</td>
<td>2.75±0.27</td>
<td>1.00±0.43</td>
<td>6.38±1.22b</td>
<td>2.56±0.55</td>
<td>2.89±0.45</td>
</tr>
<tr>
<td>C20:2 n-6</td>
<td>0.48±0.05a</td>
<td>0.22±0.01a</td>
<td>0.87±0.06</td>
<td>0.56±0.04</td>
<td>0.59±0.02</td>
<td>0.25±0.03</td>
<td>0.64±0.12a</td>
<td>1.21±0.09</td>
<td>0.66±0.01</td>
</tr>
<tr>
<td>C20:3 n-6</td>
<td>0.17±0.01a</td>
<td>0.29±0.02a</td>
<td>0.18±0.03</td>
<td>0.12±0.01</td>
<td>0.32±0.03</td>
<td>0.13±0.01</td>
<td>0.31±0.03a</td>
<td>0.40±0.04</td>
<td>0.18±0.03</td>
</tr>
<tr>
<td>C20:4 n-6</td>
<td>2.90±0.43a</td>
<td>3.94±0.54a</td>
<td>7.31±1.32</td>
<td>7.80±1.67</td>
<td>4.74±0.56</td>
<td>6.76±0.09</td>
<td>3.20±0.02b</td>
<td>10.83±2.23</td>
<td>5.86±1.32b</td>
</tr>
<tr>
<td>C20:5 n-3</td>
<td>5.59±1.98a</td>
<td>3.66±0.65a</td>
<td>7.38±1.64</td>
<td>8.58±1.43</td>
<td>7.91±0.07</td>
<td>5.23±1.98</td>
<td>2.24±0.10</td>
<td>7.92±1.65</td>
<td>9.73±1.66</td>
</tr>
<tr>
<td>C22:5 n-3</td>
<td>1.72±0.87a</td>
<td>2.58±0.06a</td>
<td>2.91±0.05</td>
<td>3.23±0.09</td>
<td>3.28±0.16</td>
<td>1.99±0.67</td>
<td>1.32±0.66</td>
<td>3.97±0.43</td>
<td>2.33±0.20a</td>
</tr>
<tr>
<td>C22:6 n-6</td>
<td>8.87±1.24a</td>
<td>12.60±1.54a</td>
<td>9.51±1.36</td>
<td>10.30±1.98</td>
<td>9.68±0.37</td>
<td>15.22±1.28</td>
<td>6.37±0.31</td>
<td>12.84±1.42</td>
<td>16.78±1.98</td>
</tr>
<tr>
<td>∑PUFA***</td>
<td>27.45±1.28a</td>
<td>33.60±2.55a</td>
<td>41.24±3.45</td>
<td>35.76±2.92</td>
<td>33.13±2.38</td>
<td>32.97±3.06</td>
<td>25.18±1.03b</td>
<td>48.31±3.44</td>
<td>41.93±3.86</td>
</tr>
<tr>
<td>n-3</td>
<td>20.34</td>
<td>24.52</td>
<td>22.7</td>
<td>24.2</td>
<td>23.62</td>
<td>23.44</td>
<td>16.31</td>
<td>27.29</td>
<td>31.73</td>
</tr>
<tr>
<td>n-6</td>
<td>7.11</td>
<td>9.08</td>
<td>18.54</td>
<td>11.56</td>
<td>9.51</td>
<td>9.53</td>
<td>8.87</td>
<td>21.02</td>
<td>10.20</td>
</tr>
<tr>
<td>n-3/n-6</td>
<td>2.86</td>
<td>2.70</td>
<td>1.22</td>
<td>2.04</td>
<td>2.48</td>
<td>2.46</td>
<td>1.84</td>
<td>3.10</td>
<td>4.71</td>
</tr>
</tbody>
</table>

*Means are the averages of 3 replicates; **Values reported are means±standard deviation; means followed by different letters in same line are significantly different (p<0.05) by Tukey’s test; ***SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids.

Table 2: Fatty acid composition of freshwater fish from the Atatürk Dam Lake (% of total FA).*
Fatty acid composition

The fatty acid contents of 12 fish species from Atatürk Dam Lake were determined by GC. Results of the fatty acid analyses of fish species can be seen in Table 2. Eighteen fatty acids were identified but lauric acid (C12:0) and tridecanoic (C13:0) acid were determined only in female *A. vorax* and *C. gibelio*. SFA contents ranged between 26.13% and 42.10% (Figure 1). The major SFA was C16:0 (Palmitic acid) (17.12–31.76%) in all specimens and the highest level was found in female *M. simack* (31.76%). This fatty acid has been reported in many studies as the major SFA in freshwater fish [18,23,24]. Palmitic acid is a key metabolite in fish and its level is not influenced by diet [25]. Stearic acid (C18:0) was the next most abundant (2.69–9.69%) and then myristic acid (C14:0) (1.33–3.68%) in all species. The fatty acids such as C12:0, C13:0, pentadecanoic acid (C15:0) and heptadecanoic acid (C17:0) were found to have a very low ratio in relation to the others. Similar results for other freshwater fish species have also been reported in the literature [4,18,24,26].

Total MUFA ranged from 23.87% to 43.84% (Figure 1). The most abundant individual MUFA in all freshwater fish were oleic acid (C18:1 n-9) (14.15–29.32%) and palmitoleic acid (C16:1 n-7) (4.61–13.20%). Both acids were found to be high in female *A. vorax*. This is in agreement with the numerous studies on the fatty acid profile of freshwater fish [18,24,27,28]. C18:1 n-9 has exogenous origin and usually reflects the type of diet of the fish [29]. The high levels of oleic acid and palmitoleic acid have been reported as a characteristic property of freshwater fish oils [30,31].

Total PUFA ranged from 25.18% to 48.31% (Figure 1). Most abundant of the n-3 PUFA was DHA (6.37–16.78%), while EPA was also present in important proportions (2.14–13.00%). The DHA amounts were higher than EPA amounts in all species except female *C. trutta*, *C. regium* and *M. simack*. These results are in accordance with literature data for freshwater fish [32]. DHA and EPA have been reported to have preventive effects on human coronary artery disease [33]. In this study all fish species had significant levels of EPA and DHA.

The contents of ALA ranged between 1.00% and 6.38% among the 12 fish species. LA (2.08–10.18%) and AA (2.90–10.83%) were the predominant n-6 PUFA in all freshwater fish. This may be due to dietary effect and saturation and elongation mechanisms [34]. The higher concentration of AA in freshwater fish could be attributed to the type of diet such as insect larvae, freshwater algae, crustacean that are rich in linoleic and linolenic acid [35]. The ability of freshwater fish to produce AA and DHA through desaturation and elongation of LA and ALA respectively increases the final concentration of AA and DHA [34]. LA and AA were the major fatty acids in female *C. gibelio* (18.10%) and male *C. auratus* (10.83%), respectively. The high levels of AA have been reported as characteristic for freshwater fish oils [31]. All fish species contained AA, which plays a role in synthesizing eicosanoids, prostanolphins and leukotriens [36]. Eicosanoids produced out of AAs have adverse cardiovascular effects such as vasoconstrictions and thrombocyte conglomeration.

The results shown in Table 2 indicated that all fish species analysed were characterised by high levels of omega-3 fatty acids (15.98–31.73%) than omega-6 fatty acids (5.15–21.02%). Generally, the n-6 fatty acid contents

![Figure 1](image-url)
of freshwater fish are higher than n-3 fatty acid contents [4,27]. However, the species we studied had higher contents of the n-3 fatty acids than n-6 fatty acids. Similar results were found in some freshwater fish [37–39]. In this study, the other long chain PUFAs were determined. C22:5 n-3 (docosapentaenoic acid, DPA) was present in appreciable amounts in all fish species (1.32–3.97%). C20:2 n-6 (eicosadienoic acid) (0.09–1.21%) and C20:3 n-6 (eicosatrienoic acid) (0.08–0.48%) were found low percentages among fish species.

The ratio of n-3/n-6 PUFAs in total lipids of all fish species changes between 1.22 female (C. gibelio) and 4.71 (C. trutta). The highest n-3/n-6 ratio was found in female C. trutta (4.71). The n-3/n-6 ratio has been suggested to be a better index for comparing the relative nutritional value of different species and it has been estimated a diet ratio from 4:1 to 1:1 during human evolution [40]. Ackman [41] found that this ratio ranged from 1.7 to 3.5 in the freshwater species. Wang et al., [26] reported that the ratio of n-3/n-6 PUFAs ranged from 0.5 to 3.8.

A balanced n-3/n-6 ratio in the diet is essential for normal growth and development and may play an important role in the prevention of coronary artery disease, diabetes hypertension and cancer, rheumatoid arthritis [42]. They also affect neuron development in infants [43]. In this study, the amounts of n-3 and n-6 fatty acids are approximately at the level advised (Table 2).

**Conclusion**

The results showed that the fish examined are a good source of n-3 PUFAs especially DHA and EPA, resulting in a very favourable n-3/n-6 ratio, especially in female C. trutta, C. mossulensis, C. regium and A. vorax. In all fish species, the n-3/n-6 ratio was >1 which is quite a satisfactory value for human diet.

**Acknowledgements:** This study was financed by the Dicle University Scientific Research Foundation (DUA-PK-08-FF-07).

**Conflict of Interest:** The authors have no conflict of interest.

**References**


