PAPER

SEASONAL VARIATION OF FATTY ACID AND AMINO ACID COMPOSITIONS IN THE MUSCLE TISSUE OF ZANDER (*SANDER LUCIOPERCA* LINNAEUS, 1758) AND THE EVALUATION OF IMPORTANT INDEXES RELATED TO HUMAN HEALTH

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ABSTRACT

In this study, the seasonal fatty acid and amino acid amounts in the muscles of the zander from Beyşehir Lake, Turkey, and their important indices for human health were evaluated. It was found that aspartic acid, glutamic acid and lysine levels in zander were dominant among the amino acids. The ratio of essential amino acids (EAA) to non-essential amino acids (NEAA) was between 0.69 and 0.78. In all seasons, the polyunsaturated fatty acid (PUFA, 89.85-109.11 mg/100g) amount in zanders was higher than saturated fatty acids (SFA, 55.08-81.89 mg/100g) and monounsaturated fatty acids (MUFA, 29.16-78.89 mg/100g). It was determined that EPA, DHA and omega-3 rates were high. The fatty acid quality indices (AI, TI, FLQ, w6/w3, h/H) were found at proper levels for human health. Summing up the results, it was found that seasons influenced both the compositions of amino acids and fatty acids of zander.

Keywords: amino acids, Beyşehir Lake, fatty acids, seasons, zander

1. INTRODUCTION

Seafood includes healthy nutrients being rich in protein, unsaturated essential fatty acids, minerals and vitamins they contain (SIDHU, 2003). Fish and shellfish play important roles for human health because of their fatty acid and amino acid varieties (GULER *et al*., 2008). Fish, as a source of food, have protein with high biological value. The building stones of the proteins consist of amino acids (WHO, 2007). Amino acids exist in seafood in important amounts and are classified as essential, non-essential and semi-essential amino acids according to their biological status (WU, 2010). These amino acids are the start-up material of many important substances for organisms, and have an important role, especially in energy metabolism. In addition, fish contains essential amino acids (threonine, valine, leucine, isoleucine, lysine, methionine, phenylalanine, tryptophan, histidine, and arginine) in proper amounts in their bodies (POLAT, 1999; VARLIK *et al*., 2011).

The polyunsaturated fatty acids in fish oil are a vital importance for human health. Consuming fish and fish oil decreases the risk of coronary heart diseases. The nutritional importance of the fish consumption is closely related to the ω-3 fatty acid content of each species. These health benefits are also in a close relationship with ω-3 PUFAs. Long-chain ω-3 PUFAs cannot be synthesized by humans, and therefore they have to be taken with food. It was demonstrated with clinical and epidemiological studies that the major source of EPA and DHA, which constitute most ω-3 PUFAs, is the seafood (GULER *et al*., 2008; CENGIZ *et al*., 2012).

DHA and EPA fatty acids are significant for the body because they could prevent coronary artery diseases (CONNOR, 2000; MOZAFFARIAN *et al*., 2005). Since DHA is the main component of the brain, eye retina and heart muscles, its importance for human health is undeniable. It was reported that EPA is beneficial in brain diseases and cancer treatment (CENGIZ *et al*., 2012). Fish are a good source of EPA and DHA. Some countries (Canada, Sweden, United Kingdom, Australia, Japan), World Health Organization (WHO) and North Atlantic Treaty Organization (NATO) declared the daily ω-3 need as 1.1.-1.6 g; and suggested that the intake should be as 0.3-0.5 g EPA+DHA and 0.8-1.1 g α-linoleic acid (ERKAN, 2013). When compared to sea fish, freshwater fish have higher C18 PUFA and lower EPA and DHA levels. Freshwater fish are generally characterized with high n6 PUFA (especially linoleic acid (18:2n6) and arachidonic acid (20:4n6)). For this reason, freshwater fish contain lower n3 PUFA and n3/n6 levels than sea fish (ÖZOĞUL *et al*., 2007; ÇELIK *et al*., 2005). In addition, the criteria such as atherogenic index (AI), thrombogenic index (TI), flesh lipid quality (FLQ) and hypocholesterolemic/hypercholesterolemic ratio (h/H) provide information on the lipid quality of fish (ULBRICHT and SOUTHGATE, 1991; ABRAMI *et al*., 1992; SANTOS-SILVA *et al*., 2002).

The fish oil and fatty acid compounds show biochemical changes depending on ecological factors and the physiological status of the fish. Even among the same species, the fatty acid component may vary according to the nutrition, region, season, gender and environmental conditions (UYSAL, 2004; ÖZOĞUL *et al*., 2007; GULER *et al*., 2007). The rich amino acid and fatty acid contents in the bodies of freshwater fish make them nutritious, and therefore they are used as animal protein source all over the world (STEFFENS, 2006).

The zander is a predatory freshwater species from the Percidae family, and is an important nutrient because of its high protein, low lipid rate, and essential ω-3 fatty acids. The zander is a lean carnivorous fish with high economic value spreading in inland waters in Turkey (UYSAL, 2004; ÇELIK *et al*., 2005).

The aim of this study was to determine the seasonal fatty acids and amino acid amounts in the muscles of the zander, and evaluate their important indices (AI, TI, FLQ, w6/w3, h/H) for human health.

2. MATERIALS AND METHODS

2.1. The study area and period

This study was conducted in 2012-2013 seasonally, in Beyşehir Lake located within the borders of Konya and Isparta in 37°47′0″N, 31°33′0″E coordinates.

2.2. Fish material

The zander (*Sander lucioperca* Linnaeus, 1758) whose height was between 34.85±1.33 cm and weight was between 395±44.76 g in 2-3 years of age were obtained from the fishermen in the Beyşehir side of the lake. The fishermen stated that they used stretching nets for fishing. A total of 32 fishes were examined throughout the study. The head, tail, fins, and viscera of zander were removed and muscle tissues of zander were kept at -70 °C until analysis of fatty acid and amino acid composition.

2.3. Amino acid analysis

Zander samples were sent to The Scientific and Technological Research Council of Turkey (TUBITAK) Marmara Research Center (MAM) Food Institute for analysis of amino acid. In amino acid analysis, an in-house method was created by modifying those of DIMOVA (2003) and GHESHLAGHI *et al*. (2008), and the sample analysis was carried out. The analysis process was performed using a UFLC (Ultra-Fast Liquid Chromatography) device and a UV detector. The amino acid analyses were conducted in triplicate.

2.4. Analysis of fatty acid methyl esters

Analysis of fatty acid methyl esters (FAME%) was carried out according to TUFAN *et al*. (2013). Lipid extraction of the samples was carried out in triplicate based on the method of BLIGH and DYER (1959), using chloroform:methanol (2:1, v/v). Methyl esters were prepared by transesterification using 2M potassium hydroxide (KOH; Merck, Darmstadt, Germany) in methanol and n-hexane (Sigma-Aldrich, Steinhein, Germany) according to the method described by ICHIHARA *et al*. (1996) with minor modification; 10 mg of extracted oil were dissolved in 2 mL n-hexane, followed by 4 mL of 2M methanolic KOH. The tube was then vortexed for 2 min at room temperature. After centrifugation at 4,000 rpm for 10 min, the hexane layer was taken for gas chromatography (GC) - Mass Spectrometry analyses.

2.5. Gas chromatography-mass spectrometry conditions

The identification of fatty acids was conducted on gas chromatography-mass spectrometry (GC-MS) device (QP2010 Ultra with AOC-20i+s model auto sampler) using a mass selective detector (GC-MS QP 2010 PLUS) equipped with GC/MS solutions software (Shimadzu, Kyoto, Japan). FAME mix standards were separated on a Restek RT-2560 column (USA Cat no: 13199 Serial no: 47623-07; 100 m × 0.25 mm internal diameter, Thickness: 0,20μm) with helium (1.0 mL/min) as the carrier gas. The injection temperature

was 240 ºC, and split ratio 50 injection mode was used. The oven temperature was programmed as follows: Column oven temperature was started as 140 ºC, then at 4th min, the temperature increased to 240 ºC and held at this temperature for 20 min, and then held at this temperature for further 50 min starting at 25th min. The MS was scanned from m/z of 45 to 550. The ion source and interface temperatures were 200 ºC and 240 ºC, respectively.
Fatty acids were identified by comparing the retention times of FAME with Supelco (tm) 37 component FAME mixture (Cat. No. 47885-U) and the results were confirmed by using WILEY/NIST 2011 library. Quantification of FAME was carried out using the area normalization method. According to the area value of each compound, area compositions were detected and results were shown as FAME%. The fatty acid content in the zander was calculated according to WEIHRAUCH *et al*. (1977).

2.6. Lipid quality indices

Lipid quality indices as atherogenicity index (AI), thrombogenicity index (TI), fish lipid quality (FLQ) and hypocholesterolemic/hypercholesterolemic ratio (h/H) were calculated with the formulas below (ULBRICHT and SOUTHGATE, 1991; ABRAMI *et al*. 1992; FERNÁNDEZ *et al*., 2007).

AI= [(12:0+(4x14:0)+16:0)]/[(n-6 PUFA+n-3 PUFA)+∑ MUFA]
IT= [14:0+16:0+18:0]/[(0.5x∑ MUFA)+0.5(n-6 PUFA)+3(n-3 PUFA)+(n-3 PUFA/n-6 PUFA)]
FLQ= (EPA+DHA)/total lipids
h/H=(C18:1+C18:2+C18:3+C20:3+C20:4+C20:5+C22:4+C22:5+C22:6)/(C14:0+C16:0

2.7. Statistical analysis

Statistical analysis was performed using the JMP 5.0.1 (SAS) package program. Analysis of variance (ANOVA) was used to compare the results the among seasons, and the Tukey's test was applied to the groups demonstrating difference ($P<0.05$) (SOKAL and ROHLF, 1987).

3. RESULTS AND DISCUSSIONS

The amino acid contents of the zander in seasonal periods are shown in Table 1. The protein contents of the zander are the lowest in spring (17.75%) and the highest in autumn (19.35%). While the protein amount in summer and winter seasons showed statistical similarities to each other ($p>0.05$), they were found to be different from the other seasons ($p<0.05$). When the amount of the amino acids of the zander, which contain 16 types of amino acids, are examined, the methionine, which is one of the essential amino acids, had the lowest value with 465.5 mg/100g and aspartic acid, which is one of the non-essential amino acids had the highest value with 3202.5 mg/100g. It was determined that ten of the amino acids (phenylalanine, lysine, valine, leucine, isoleucine, tyrosine, glycine, proline, arginine and alanine) were at maximum level in autumn; five of them (histidine, threonine, aspartic acid, glutamic acid and serine) were at maximum level in summer; and one of them (methionine) was highest in winter. It was also seen that in spring, when the zander reproduce, all the amino acids except for lysine were at the lowest level. Lysine, leucine, threonine and valine were dominant in EAA. The aspartic acids, glutamic acid, alanine and serine were at the highest level in NEAA. Similarly, MOHANTY *et al*. (2012)

found that in giant river-catfish (*Sperata seenghala*) histidine, threonine and leucine from EAA; and glutamic acid, aspartic acid and serine amino acids from NEAA were dominant. It was observed that the highest values of the total essential amino acids (ΣEAA) were in autumn; the highest values of the total non-essential amino acids (ΣNEAA) were in summer. The ΣEAA/ΣNEAA ratio is an index that shows the protein quality (SWENDSEID *et al*., 1963). The ΣEAA/ΣNEAA ratio, which was obtained seasonally, changed between 0.69-0.78. IWASAKI and HARADA (1985) reported the EAA/NEAA ratio as being 0.70 in average in seawater fish species. MOHANTY *et al*. (2012) noted the ΣEAA/ΣNEAA ratio of giant river-catfish as being 0.89. In another study, the ΣEAA/ΣNEAA ratio (1.08) of *Puntius sophore*, which are among freshwater fish, was found to be higher than those reported in other studies (MAHANTY *et al*., 2014). It is considered that the differences between the ΣEAA/ΣNEAA ratios are resulted from the fish species, seasons, nutrition and location.

Table 1. Seasonal amino acid contents of zander samples.

Amino acids (mg/100g)	Spring	Summer	Autumn	Winter
Protein (%)	17.75±0.01^{a}	18.75±0.11^{b}	19.35±0.05^{c}	18.73±0.26^{b}
Methionine*	465.5±7.78^{a}	509±1.41^{b}	499±0.00^{b}	513±5.66^{b}
Phenylalanine*	661±9.90^{a}	687.5±6.36^{b}	812±1.41^{c}	749±2.83^{d}
Lysine*	2052.5±17.68^{a}	1975±2.83^{b}	2544.5±12.02^{c}	1969.5±6.36^{b}
Histidine*	492±12.73^{a}	643±1.41^{b}	628±28.28^{b}	632.5±26.16^{b}
Valine*	790.5±13.44^{a}	861±1.41^{b}	928±7.07^{c}	887±11.31^{d}
Leucine*	1119.5±19.09^{a}	1181±5.66^{b}	1317.5±7.78^{c}	1198±9.90^{b}
Isoleucine*	701.5±12.02^{a}	744±2.83^{b}	839.5±3.54^{c}	809±5.66^{d}
Threonine*	808±12.73^{a}	933±1.41^{b}	878.5±0.71^{c}	836.5±2.12^{d}
Tyrosine	579±0.00^{a}	603±1.41^{b}	682.5±2.12^{c}	630±1.41^{d}
Glycine	613±8.49^{a}	706.5±4.95^{b}	764±1.41^{c}	682±2.83^{d}
Proline	496±8.49^{a}	543±24.04^{ab}	604.5±0.71^{c}	579.5±2.12^{bc}
Arginine	724.5±10.61^{a}	744±1.41^{a}	851.5±0.71^{b}	806±2.83^{c}
Alanine	1034.5±16.26^{a}	1116±31.11^{b}	1194±1.41^{c}	1125±2.83^{bc}
Aspartic Acid	2779.5±47.38^{a}	3202.5±31.82^{b}	2783.5±3.54^{a}	3079±16.97^{c}
Glutamic Acid	2781±42.43^{a}	3174±2.83^{b}	3097.5±4.95^{b}	2985±4.24^{c}
Serine	809±14.14^{a}	899±2.83^{b}	851.5±4.95^{c}	866±7.07^{bc}
ΣEAA	7090.5±70.00^{a}	7533.5±23.33^{b}	8447±9.90^{c}	7594.5±4.95^{b}
ΣNEAA	9816.5±147.79^{a}	10988±79.20^{b}	10829±7.07^{b}	10752.5±14.85^{b}
ΣAA	16907±217.79^{a}	18521.5±55.86^{b}	19276±2.83^{c}	18347±9.90^{b}
ΣEAA/ΣNEAA	0.72	0.69	0.78	0.71

EAA*: Essential amino acid, NEAA: Non-essential amino acid, AA: Amino acid. Different letters (a,b,c,d) in the same line indicates statistical differences among seasons ($p<0.05$).

The World Health Organization recommended methionine, phenylalanine, lysine, histidine, valine, leucine, isoleucine and threonine requirements for adults of 10, 25, 30, 10, 26, 39, 20, respectively and 15 mg amino acid/kg body weight per day (WHO, 2007). When the results of our study are evaluated according to the reports of WHO (2007), it is clear that if a person whose weight is 70 kg consumes 200 g meat of zander, he or she receives methionine, lysine, histidine, isoleucine and threonine amino acids; and if one consumes 300 g zander, all his or her amino acid needs could be met.
The fatty acid contents of the zander in each season are shown in Table 2.

Table 2. Seasonal fatty acid contents of zander samples.

Fatty Acids mg/100g	Spring	Summer	Autumn	Winter
C14:0	1.79±0.32^{a}	2.38±0.13^{a}	3.10±0.25^{a}	5.80±0.79^{b}
C15:0	0.74±0.01^{a}	0.72±0.12^{a}	0.87±0.19^{a}	1.65±0.14^{b}
C16:0	38.05±0.60^{a}	51.87±0.93^{b}	54.05±0.90^{b}	52.99±3.70^{b}
C17:0	0.96±0.09^{a}	1.14±0.09^{ab}	1.14±0.02^{ab}	1.76±0.34^{b}
C18:0	10.65±0.18^{a}	18.99±0.25^{b}	15.35±0.10^{bc}	11.83±1.96^{ac}
C20:0	0.22±0.03^{a}	0.31±0.01^{a}	0.51±0.02^{b}	0.56±0.06^{b}
C21:0	1.84±0.10^{a}	2.03±0.15^{a}	3.49±0.36^{b}	5.67±0.45^{c}
C24:0	0.84±0.04^{a}	0.80±0.00^{a}	0.77±0.07^{a}	1.65±0.10^{b}
ΣSFA	55.08±0.93^{a}	78.24±1.42^{b}	79.28±0.14^{b}	81.89±3.95^{b}
C16:1	7.51±0.16^{a}	5.50±0.27^{a}	12.65±1.02^{a}	25.31±3.95^{b}
C17:1	0.75±0.00^{a}	0.47±0.00^{a}	0.81±0.10^{a}	2.02±0.22^{b}
C18:1n9t	0.13±0.00^{a}	0.24±0.01^{ab}	0.31±0.00^{b}	0.57±0.08^{c}
C18:1n9c	20.51±0.53^{a}	22.42±0.99^{a}	36.17±2.00^{b}	49.48±0.77^{c}
C20:1	0.59±0.10^{a}	0.53±0.00^{a}	0.63±0.12^{a}	1.50±0.18^{b}
ΣMUFA	29.49±0.58^{a}	29.16±1.27^{a}	50.58±3.24^{b}	78.89±5.20^{c}
C18:2n6c	4.68±0.05^{a}	5.01±0.45^{ab}	8.46±0.47^{b}	12.05±0.57^{c}
C18:3n6	0.30±0.19^{a}	0.55±0.00^{a}	0.57±0.17^{a}	1.26±0.00^{b}
C20:2n6	0.17±0.00^{a}	0.42±0.00^{b}	0.69±0.03^{c}	0.63±0.00^{c}
C20:3n6	0.60±0.01^{a}	0.42±0.03^{a}	0.55±0.07^{a}	0.90±0.06^{b}
C20:3n3	0.28±0.00^{ab}	0.13±0.03^{a}	0.34±0.07^{b}	0.86±0.04^{c}
C20:4n6	18.33±0.30^{ab}	19.01±0.16^{a}	15.56±0.80^{b}	18.06±1.06^{ab}
C20:5n3	9.19±0.22^{a}	11.08±0.15^{a}	23.04±1.32^{b}	15.47±1.19^{c}
22:5n3	8.14±0.38^{bc}	5.35±0.03^{a}	6.69±0.02^{ab}	9.29±0.63^{c}
C22:6n3	48.17±1.23^{ab}	53.28±1.72^{a}	42.76±3.29^{b}	50.60±1.58^{ab}
ΣPUFA	89.85±1.06^{a}	95.26±1.47^{ab}	98.66±4.81^{ab}	109.11±4.71^{b}

Different letters (a,b,c,d) in the same line indicates statistical differences among seasons ($p<0.05$).

It was observed that in all seasons, the PUFAs are the highest (ave. 43.32%), MUFA's are the lowest (ave. 19.64%). The palmitic acid (C16:0) has the highest amount among saturated fatty acids. The 16:0 amount was detected between 18.52%-24.52%. Similarly, in a study conducted by JANKOWSKA *et al*. (2003), C16:0 was determined as 19.91% in wild zander, 20.24% in cultured zander (fed artificial feed) and 20.33% in cultured zander (fed natural food), respectively. The total saturated fatty acid (∑SFA) were found in spring, summer, autumn and winter as 55.08 mg/100g, 78.24 mg/100g, 79.28 mg/100g and 81.89 mg/100g, respectively; which shows the values in spring were different from the other seasons ($p<0.05$). Among the monounsaturated fatty acids (MUFA), palmitoleic acid (C16:1), cis-10-heptadecanoic acid (C17:1) and cis-11-eicosenoic acid (C20:1) values were observed minimum in summer; while the lowest values of elaidic acid (C18:1n9t) and oleic acid (C18:1n9c) were found in spring. The values of C16:1, C17:1, C20:1, C18:1n9t and C18:1n9c in winter was found different from other seasons ($p<0.05$). The ∑MUFA amounts were determined between 29.49-78.89 mg/100g and there were significant differences among the seasons ($p<0.05$).

Polyunsaturated fatty acids (∑PUFA) showed constant increase from spring till winter. The majority of ∑PUFA consisted of docosahexaenoic acid (C22:6n3) DHA, arachidonic acid (C20:4n6) and eicosapentaenoic acid (C20:5n3) EPA. In all seasons, the DHA amount was found higher than the other PUFA amounts at a significant level ($p<0.05$) and was determined as 48.70 mg/kg in average.

The SFA (28.62%-30.01%), MUFA (13.79%-27.57%) and PUFA (38.19%-48.95%) amounts of zander in this study were found similar to the results reported in zander as 31.8%, 13.8% and 42.4%, respectively in the study conducted on seawater and freshwater fish species of Turkey by ÖZOĞUL *et al*. (2007). In another study, the SFA, MUFA and PUFA contents of the zander were determined in Seyhan Lake as 32.9%, 28.0%, 20.8%, in Eğirdir Lake as 30.5%, 20.3%, 30.5% (ÇELIK *et al*., 2005).

The fatty acid contents of the zander examined in this study were more consistent with the results of the zander of Eğirdir Lake than those from Seyhan Lake. However, the PUFA rates were found to be lower than our results. It is considered that this difference occurs from the undetected % fatty acid rates being high in the study conducted by ÇELIK *et al*. (2005). In another study, the SFA%, MUFA% and PUFA% rates of the wild zander were found as 27.84%, 21.36% and 50.80, respectively (JANKOWSKA *et al*., 2003).

The PUFA/SFA ratio must be minimum 0.45 (JUSTI *et al*., 2003; TUFAN *et al*., 2011). The data of this study were 1.22-1.63, which is consistent with the values recommended in terms of health (Table 3). The PUFA/SFA ratio determined in spring (1.63) was statistically different from those determined in other seasons ($p<0.05$). ÖZOĞUL *et al*. (2007) reported that the PUFA/SFA ratio changed between 0.78-1.56 is freshwater fish, and in zander this ratio was 1.33. This PUFA/SFA ratio was found to be similar with our results especially recorded in winter.

It is reported that the atherogenic (AI) and thrombogenic (TI) indices that are higher than (>1.0) is harmful for human health (OURAJI *et al*., 2009). If this value gets lower, the risk of coronary heart diseases decreases (CUTRIGNELLI *et al*., 2008). The AI (0.38-0.49) and TI (0.22-0.31) values obtained in this study were found lower than this value in all seasons (Table 3), and it was also determined that there were no risks for human health.

SOUSA BENTES *et al*. (2009) reported that the h/H ratio of fatty acids is the indicator of whether the fat in the product is nutritionally adequate. The h/H ratio was found between 2.17-2.77 in this study, and no differences between spring and winter, also between summer and autumn were determined ($p<0.05$).

Table 3. Fatty acid ratios and lipid quality indexes.

Fatty acid	Spring	Summer	Autumn	Winter
∑PUFA/∑SFA	1.63±0.05^{a}	1.22±0.04^{b}	1.24±0.06^{b}	1.33±0.01^{b}
∑PUFA/∑MUFA	3.05±0.10^{a}	3.27±0.19^{a}	1.96±0.22^{b}	1.39±0.15^{b}
EPA+DHA	57.36±1.01^{a}	64.36±1.57^{a}	65.8±4.61^{a}	66.06±2.77^{a}
∑n3 PUFA	65.78±0.64^{a}	69.84±1.57^{a}	72.83±4.56^{a}	76.21±4.57^{a}
∑n6 PUFA	24.07±0.43^{a}	25.42±0.1^{b}	25.83±0.25^{b}	32.9±0.14^{c}
∑n3/∑n6	2.73±0.02^{ab}	2.75±0.07^{a}	2.82±0.15^{a}	2.32±0.13^{b}
∑n6/∑n3	0.37±0.00^{a}	0.36±0.01^{a}	0.36±0.02^{a}	0.43±0.02^{b}
AI	0.38±0.02^{a}	0.49±0.01^{b}	0.45±0.01^{bc}	0.41±0.00^{ac}
TI	0.22±0.01^{a}	0.31±0.01^{b}	0.28±0.01^{bc}	0.25±0.01^{ac}
FLQ	32.89±0.67^{a}	31.76±0.97^{a}	28.79±1.80^{ab}	24.47±0.71^{b}
h/H	2.77±0.08^{a}	2.17±0.05^{b}	2.35±0.02^{b}	2.70±0.07^{a}

AI: atherogenic index, TI, thrombogenic index, FLQ: flesh-lipid quality, h/H: hypocholesterolemic/hypercholesterolemic ratio. Different letters (a,b,c,d) in the same line indicates statistical differences among seasons ($p<0.05$).

If the FLQ value is high, this indicates that there are nutrient lipids with good quality (ABRAMI *et al*., 1992). The highest FLQ values were seen in spring (32.89), and the lowest in winter (24.47). The difference between them was significant ($p<0.05$) (Table 3). The FLQ values in winter were found to be similar only to those in autumn ($p>0.05$). The EPA+DHA amounts in zander were determined between 57.36-66.06 mg/100g (Table 3). There were differences between the seasons ($p>0.05$). The EPA+DHA amounts in the zander caught in the same lake were determined as 29.23%, 21.32%, 28.27% and 24.24% for spring, summer, autumn and winter, respectively (GULER *et al*., 2007). These results show similarity with this study except for the summer season. The n6/n3 ratio is recommended max. 4 by the UK Department of Health (JUSTI *et al*., 2003). The ∑n6/∑n3 ratios in this study were found in the recommended limit value. The ∑n6/∑n3 ratio in winter (0.43) was found higher ($p<0.05$) than the other seasons (0.36-0.37) (Table 3). JANKOWSKA *et al*. (2003) found the ∑n6/∑n3 ratio of the wild zander as 0.31. ÖZOĞUL *et al*. (2007) determined that the n6/n3 ratio of zander is 0.46 similarly with our winter data. On the other hand, GULER *et al*. (2007) reported that n6/n3 ratio of zander is between 0.67-1.39 in all seasons.

4. CONCLUSIONS

As a conclusion, the zander, which are also called freshwater seabass, have an important fatty acid composition. It was determined that the EPA, DHA and omega-3 rates of the zander, which played an important role in human nutrition are high. In addition, the fatty acids quality indexes were found at proper levels for human health. Moreover, it was observed that the zander have high protein and rich amino acid content although the rate of amino acids changes according to the seasons. The lowest amino acid rates were found in spring, the period of reproduction. At the end of the seasonal examination of amino

acid and fatty acid contents of the zander, it has been observed that these contents have a nutrient function for a healthy and balanced diet.

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