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Research Article

Nutrient quality of the fillet and gonads of the European flounder (Platichthys flesus) in the Southern Black Sea

Seval DERNEKBAŞI[1,*], Mehmet Emin ERDEM[2], İsmihan KARAYÜCEL[2]

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[1] Sinop University, Fisheries Faculty, Department of Aquaculture, Sinop, Türkiye; sevalyaman@hotmail.com; ismihank@hotmail.com
[2] Sinop University, Fisheries Faculty, Department of Fish Processing Technology, Sinop, Türkiye; eminerdem68@hormail.com
*Corresponding Author

Abstract: Platichthys flesus is an important fisheries resource in the all Black Sea used for human consumption. It is an economic species, being caught for commercial purposes both in Europe and Türkiye. Therefore, the present study aimed to determine the nutritional quality indices and changes in biochemical and fatty acid compositions in flounder (Platichthys flesus) fillets and gonads caught from the Southern Black Sea in the reproduction period. While the moisture and lipid contents of flounder fillets were higher than the gonads, the protein and ash contents were determined to be higher in the gonads than in the fillets. The differences among them were found to be statistically significant (P<0.05). C14:0, C18:0, C16:1, C18:1n-9c, C20:1, C18:2n-6c and C18:3n-3 fatty acids in fillets, C16:0, C20:4n-6, C20:5n-3 and C22:6n-3 fatty acids in gonads were dominant. There were statistical differences between them (P<0.05). Among total fatty acids, SFA and PUFA were detected at higher rates in gonads and MUFA in fillets (P<0.05). The index of thrombogenicity (IT), hypocholesterolemic/ Hypercholester-olemic (h/H) and flesh lipid quality (FLQ) values were determined higher in gonads, and the index of atherogenicity (IA) value was determined higher in fillets. While there was no statistical difference between IT and h/H values (P>0.05), the differences between IA and FLQ values were found to be significant (P<0.05). As a result, it is recommended to consume flounder, having commercial importance in Black Sea and important nutritional value in terms of protein and fatty acids compositions.

Keywords: European flounder; fatty acids; IA; IT; FLQ; h/H

Güney Karadeniz'deki Avrupa pisi balığı (Platichthys flesus) filetosu ve gonadlarının besin kalitesi

Özet: Platichthys flesus tüm Karadeniz'de insan tüketimi için kullanılan önemli bir balıkçılık kaynağıdır. Hem Avrupa'da hem de Türkiye'de ticari amaçla avlanan ekonomik bir türdür. Bu nedenle bu çalışmada, Güney Karadeniz'den avlanan pisi balığı (Platichthys flesus) fileto ve gonadlarının üreme döneminde beslenme kalite indeksleri ile biyokimyasal ve yağ asidi kompozisyonlarındaki değişimlerin belirlenmesi amaçlandı. Pisi balığı filetolarının nem ve lipit içerikleri gonadlara göre daha yüksek iken, protein ve kül içeriklerinin gonadlarda daha yüksek olduğu belirlendi. Aralarındaki farklar istatistiksel olarak anlamlı bulunmuştur (P<0,05). Filetolarda C14:0, C18:0, C16:1, C18:1n-9c, C20:1, C18:2n-6c ve C18:3n-3 yağ asitleri, C16:0, C20:4n-6, C20: Gonadlarda 5n-3 ve C22:6n-3 yağ asitleri baskındı. Aralarında istatistiksel farklar vardı (P<0.05). Toplam yağ asitlerinden SFA ve PUFA gonadlarda, MUFA ise filetolarda daha yüksek oranda tespit edildi (P<0.05). Trombojenite indeksi (IT), hipoko-lesterolemik/hiperkolesterolemik (h/H) ve et lipid kalitesi (FLQ) değerleri gonadlarda, atero-jenite indeksi (IA) değeri ise filetolarda daha yüksek olarak belirlendi. IT ve h/H değerleri arasında istatistiksel bir fark bulunmazken (P>0.05), IA ve FLQ değerleri arasındaki farklar ise anlamlı bulundu (P<0.05). Sonuç olarak Karadeniz'de ticari öneme sahip, protein ve yağ asitleri bileşimi açısından önemli besin değeri olan pisi balığının tüketilmesi önerilmektedir.

Anahtar Kelimeler: Avrupa pisi balığı; yağ asitleri; IA; IT; FLQ; h/H

1. Introduction

Nowadays, healthy nutrition has become important for leading a quality life. Adequate and balanced nutrition is an important factor in a healthy life. Fish is one of the most important contributors to a healthy human diet because it contains important nutrients [1-2]. Depending on the number of fatty acids that cannot be synthesized by human bodies and the number of double bonds in the carbon chain, saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), and polyunsaturated fatty acid (PUFA) amounts and ratios are used to determine the nutritional importance of fats in foods [3]. Indices developed for fatty acids are used to determine food quality. Among PUFA, linoleic acid (LA, C18: 2 n-6) and linolenic acid (LNA, C18: 3 n-3) are essential fatty acids and the synthesis of arachidonic acid (ARA, C20:4 n-6)) from LA, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) from LNA reveals the importance of these fatty acids [4-5].

Human beings need PUFA from birth to death. These are essential fatty acids and must be taken into the body from outside through food. The therapeutic properties of the ω-3 fatty acids EPA and DHA, which are commonly found in fish and other seafood, and their contribution to quality of life have been conclusively demonstrated by research. Omega 3 fatty acids have been found to have a significant effect on the prevention of diseases such as heart attack, cardiovascular diseases, depression, migraine headaches, Alzheimer's, early dementia, joint rheumatism, diabetes, high cholesterol, and blood pressure, some types of allergies and cancer [6-7]. Its contribution to children's eye health, especially brain development, has been conclusively proven. For this reason, it is recommended that the amount of fish and fish products should be consumed between 100 g [8] and 300 g [9], preferably oily fish, at least two meals a week to increase the benefits and feel the health effects [10-11].

Marine lipids have long been recognized for their health effects on humans and this is primarily due to their fatty acid composition and distribution [12]. Therefore, increasing the consumption of fish or fish products that are rich in PUFA of the n-3 family and poor in PUFA of the n-6 family is important for human health [13]. In the investigated flatfish, up to 50% of the fatty acids were PUFA and 18% to 25% were SFA [14-15-16-17-18-19].

Numerous studies have been conducted to determine the nutrient composition of fish and other seafood, especially the distribution of fatty acids [20-13-21-22]. European flounder (*Platichthys flesus*) fillets typically contain high-quality protein, essential fatty acids (such as omega-3), vitamins (such as vitamin D and B12), and minerals (such as selenium and phosphorus). However, no studies on the nutritional composition of flounder gonads have been found in the literature. Therefore, a comparative study on the nutritional composition of flounder gonads and fillets was designed. The current study was conducted to determine the changes in the nutritional composition, fatty acid composition necessary for human health and nutritional quality indices in both fillets and gonads of flounder (*Platichthys flesus*) caught from Sinop during the breeding period. For this purpose, different edible parts of this fish species (fillet and gonad) were distinguished and evaluated separately, and a comparative analysis of both parts was made.

2. Material and Method

2.1. Fish material

In this study, European flounder (*Platichthys flesus*) caught from Sinop during the breeding period in 2021 was used. Sampling was done in January and February, the spawning period in the Black Sea, to determine the change in fatty acids in fish fillet and the effect of egg formation on fatty acids. A total of 10 female fish, 5 each month, were obtained directly from the boats. The fish were transported to the Sinop University Faculty of Fisheries Feed Production and Technology laboratory under cold chain conditions. After length and weight measurements, the gonads and fillets of the cleaned fish were separated. Gonads and fillets were homogenized separately and made ready for analysis. Each homogenized sample was packaged in 3 parallels and stored at -20ºC.

2.2. Biochemical Analysis

Gonad and fish fillet samples were analyzed according to the standard methods of the Association of Official Analytical Chemists [23]. The samples for dry matter detection were dried at 105°C until a constant weight was achieved. The ash content of samples was determined after being burned at 550°C for 6 h in a muffle furnace. Crude protein amount was analyzed by the Kjeldahl method, and crude lipid was determined after extraction with petroleum ether by the Soxhlet method.

2.3. Fatty Acid Analysis

Total lipid was determined by modified Bligh and Dyer Method [24]. 0.25 g of extracted lipid from fish fillet and gonad was thawed by adding 4 ml of heptane and 0.4 ml of 2N KOH was added. This mixture was stirred in vortex for 2 minutes, then centrifuged at 5000 rpm for 5 minutes. After centrifugation, 1.5-2 ml of the heptane phase was collected and transferred to glass tubes for GC/MS analysis. The injection of samples into the device was performed with the autosampler AI 1310. Samples were analyzed by Thermo Scientific ISQ LT model GC/MS gas chromatography by spectrometer. For this analysis, with 0.25µm film thickness was used a Trace Gold TG-WaxMS capillary column (Thermo Scientific code: 26088-1540) in 0.25µm inner diameter and 60µm length. The injection block temperature was adjusted to 240°C and the column temperature program to be increased from 100°C to 240°C. Helium gas (1 ml/min) was used as a carrier gas and 1:20 split ratio was applied. The MS unit (ISQ LT) was used in electron ionization mode. Fatty acids were defined by comparing the standard FAME mixture of 37 components [Chem-Lab Fame mix (37C) standard solution; Art. Nr. CL40. 13093; Lot Nr. 221.561.102.100] with respect to their arrival time.

2.4. Indices of the nutrition quality of fillet lipids

The lipid nutritional value of the fillets is referred to as the index of atherogenicity (IA), the index of thrombogenicity (IT), the flesh lipid quality (FLQ) measurements and hypocholesterolemic/ Hypercholesterolemic (h/H). These measurements were determined using the following formulas [25-26-27]

$$IA = \frac{[(4\times C14:0) + C16:0 + C18:0]}{(\Sigma MUFA + n\text{-}6\ PUFA + n\text{-}3\ PUFA} \quad (2.1)$$

$$IT = \frac{(C14:0 + C16:0 + C18:0)}{(0.5\times\Sigma MUFA + 0.5\times n\text{-}6PUFA + 3\times n\text{-}3PUFA) + (n\text{-}3PUFA/n\text{-}6\ PUFA)} \quad (2.2)$$

$$FLQ = \frac{C20:5\ n3 + C22:6\ n3}{\Sigma total\ FA} \quad (2.3)$$

$$h/H=\frac{C18:1n\text{-}9+C18:2n\text{-}6+C20:4n\text{-}6+C18:3n\text{-}3+C20:5n\text{-}3+C22:5n\text{-}3+C22:6n\text{-}3}{C14:0+C16:0} \quad (2.4)$$

2.5. Statistical Analysis

Anderson-Darling and Levene's tests were used for the homogeneity of variances and equality of variance of the datas, respectively. Mann-Whitney U test was performed to look at the mean differences between the groups and to determine whether there was a significant difference between them. Before the statistical analysis, the square root transformations of the percent data were made for the homogeneity of the variances. Differences were considered significant when $p<0.05$. All analyses results were presented as mean values±SE. Analyzes were performed using Minitab 17 (Minitab Inc., State College, PA, USA) software for Windows.

3. Results and Discussion

In terms of biochemical composition between the gonads and fillets of fish, moisture and lipid contents were determined to be higher in the fillets, and protein and ash contents were higher in the gonads (Table 1). The differences between them were found to be statistically significant ($P<0.05$).

Table 1. *Biochemical composition of the gonad and fillets of the European flounder (Platichthys flesus) (% fresh weight)*

	Gonads	Fillets
Moisture (%)	67.54 ± 0.53^{a}	76.88 ± 0.58^{b}
Protein (%)	30.21 ± 3.17^{b}	21.35 ± 0.25^{a}
Lipid (%)	1.06 ± 0.13^{a}	1.99 ± 0.44^{b}
Ash (%)	3.50 ± 0.13^{b}	2.01 ± 0.10^{a}

Data are mean ± SE. Means with different superscript letter in a row are significantly different ($p>0.05$)

The health effects of marine lipids on humans have long been known. Aquatic organisms (fish, invertebrates, algae and other aquatic products) are the main natural sources of PUFA in the human diet. Fisheries, which are also rich in biochemical composition, contain high protein, are rich in essential amino acids, and are of high quality in terms of marine lipids, increasing their importance in the diet. The moisture, protein, lipid and ash were 80.55%, 17.64%, 1.20% and 1.07%, respectively, in a study carried out on the fillet of the European plaice (*Pleuronectes platessa*) in Norway [28]. The fillet biochemical compositions of European flounder caught in the North Sea were reported approximately 81%, 16.6%, 0.8% and 0.9% in terms of moisture, protein, lipid and ash [17]. The nutritional composition of the mature egg is very important for the survival of the egg and subsequently the larvae. Therefore, in many fish species, gonads often have different nutritional compositions compared to fillets. In the current study, the gonad protein ratio was determined to be higher than the fillet protein ratio.

C14:0, C18:0, C16:1, C18:1n-9c, C20:1, C18:2n-6c and C18:3n-3 fatty acids in fillets and C16:0, C20:4n-6, C20:5n-3 and C22:6n-3 fatty acids in gonads were predominant (Table 2). There were statistical differences between them ($P<0.05$). Among total fatty acids, SFA and PUFA were detected at higher rates in gonads and MUFA in fillets ($P<0.05$). Figure 1 was showed changes in the predominant fatty acids in European flounder (*Platichthys flesus*) fillet and gonads.

Table 2. *Fillet fatty acid compositions of the gonad and fillets of the European flounder (Platichthys flesus) (% total fatty acids)*

	Fillets	Gonads
C14:0	5.11±0.53[b]	3.19±0.15[a]
C15:0	1.21±0.09[a]	1.77±0.04[b]
C16:0	14.07±0.50[a]	18.65±0.94
C17:0	0.82±0.05[a]	1.79±0.03[a]
C18:0	4.58±0.20[a]	4.25±0.27[a]
C20:0	0.40±0.14[b]	0.15±0.02
C21:0	0.23±0.07[b]	0.06±0.02[a]
C22:0	0.51±0.22[b]	0.03±0.01[a]
C23:0	0.21±0.05[a]	0.29±0.14[a]
C24:0	0.89±0.14[a]	0.70±0.08[a]
ΣSFA	28.03±0.21[a]	30.86±0.72[b]
C14:1	0.77±0.05[b]	0.53±0.09[a]
C15:1	0.56±0.13[a]	0.79±0.19[a]
C16:1	9.60±0.37[b]	4.87±0.38[a]
C17:1	1.67±0.08[a]	2.11±0.21[b]
C18:1 n-9c	13.76±0.97[b]	11.71±0.47[a]
C18:1n-9t	4.89±0.71[b]	4.00±0.29[a]
C20:1	3.02±0.41[b]	1.27±0.18[a]
C20:1 n-9	1.72±0.30[b]	1.03±0.10[a]
C24:1	0.67±0.11[b]	0.22±0.03[a]
ΣMUFA	36.67±1.31[b]	26.35±0.47[a]
C18:2 n-6c	3.85±0.22[b]	3.27±0.03[a]
C18:2 n-6t	0.45±0.05[a]	0.45±0.05[a]
C18:3 n-3	1.76±0.37[b]	1.13±0.12[a]
C18:3 n-6	0.49±0.10[b]	0.15±0.02[a]
C20:2	0.93±0.15[b]	0.50±0.07[a]
C20:3 n-3	0.60±0.05[a]	0.87±0.02[b]
C20:3 n-6	0.36±0.07[a]	0.75±0.31[b]
C20:4 n-6	4.06±0.25[a]	4.21±0.12[a]
C20:5n-3	9.80±0.09[a]	11.80±0.26[b]
C22:2	0.36±0.09[b]	0.15±0.02[a]
C22:6 n-3	12.40±0.61[a]	19.48±0.52[b]
ΣPUFA	35.06±1.19[a]	42.70±1.18[b]
Σn-3PUFA	24.56±0.88[a]	33.28±0.86[b]

Σn-6PUFA	9.21±0.16[b]	8.82±0.29[b]
n-3/n-6	2.67±0.09[a]	3.78±0.04[b]
PUFA/SFA	1.25±0.04[a]	1.39±0.07[b]
DHA/EPA	1.27±0.07[a]	1.65±0.02[b]
DHA+EPA	22.20±0.69[a]	31.28±0.78[b]

Data are reported as mean±standard errors of three replicate (3). Means with different superscript letter in a row are significantly different (p>0.05). SFA: Saturated fatty acids, MUFA: Monounsaturated fatty acids, PUFA: Polyunsaturated fatty acids, DHA: Docosahexaenoic acid, EPA: Eicosapentaenoic acid

Fish are the main source of n-3 PUFAs in the human diet. This feature arises from the fatty acid composition and the amount of unsaturated fatty acids in fish [12]. Unsaturated fatty acids include both MUFA and PUFA. There is a consensus regarding the positive effects of PUFA on human health [29-30-31]. Many researchers reported that factors such as seasonal changes, species, sex, size, food availability, geographic location, breeding status, fishing season, water temperature and salinity affect the amount of fatty acids in fish species [32-33-34]. Thornes [35] stated that in the flatfish, 50% of the fatty acids contain PUFA and between 18% and 25% of the fatty acids are saturated fatty acids. In the current study, fatty acids, including palmitic, stearic, oleic acids, and DHA, were abundant in the egg and the fillet of flounder regardless of sampling time. Prato and Biandolino [36] reported that oleic acid is the most abundant MUFA in most marine fish. MUFA and SFA are used as metabolic energy sources for these species, and long-chain n-3 fatty acids are essential mainly for structural purposes, i.e. as components of membrane phospholipids. In addition, MUFA is converted to energy more efficiently through the β-oxidation process than n-6 PUFA. This observation can be explained by the fact that SFA and MUFA are largely represented in neutral lipids [37].

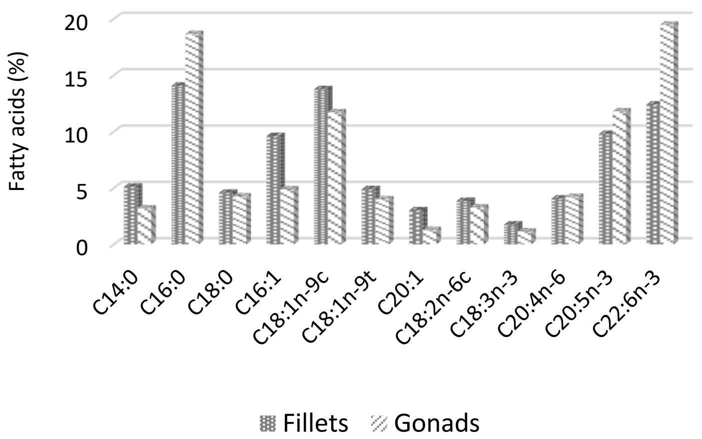

Figure 1. Changes in the predominant fatty acids in European flounder (*Platichthys flesus*) fillet and gonads.

The balanced presence of LNA and LA in the diet of fish larvae provides an optimal survival rate [38]. Likewise, the presence of LNA, ARA and EPA increases the quality of fish egg [39]. LA is a precursor to ARA, which is reported to be advantageous for the cardiovascular health of consumers only when present at low levels, due to its antagonistic effect against the health benefits of n3 fatty acids [40-41]. Garaffo et al. [25] reported very low amounts of ARA content in tuna egg (*Thunnus thynnus*). In the current study, both LA and ARA levels were very high levels in the gonad and the fillet.

Seafood contains high and balanced amounts of PUFA, especially EPA and DHA [29-42]. In addition to providing people with high-quality proteins, fish consumption satisfies nutritional requirements for essential n-3 fatty acids, primarily EPA and DHA, which are two long-chain polyunsaturated fatty acids (LC-PUFA) mainly present in fish [43]. DHA also plays an important role in the reproductive activities of females. It is transferred from the muscles to the liver and gonads and affects egg quality and survival in the larva, and also plays an important role in adaptation processes [44]. It has been reported that DHA and EPA are among the most abundant fatty acids in flatfish, containing more than 40% of total fatty acids for starfish (*Platichthys platessa*) and yellowtail flounder (*Harbour ferruginea*) [17]. While DHA is high in some species such as megrim (*Lepidorhombus whiffiagonis*), yellowtail flounder (*Limanda ferruginea*) and spiny stingray (*Dasyatis pastinaca*), EPA is higher in flat fish such as plaice (*Pleuronectes platessa*), Alaska flounder (*Pleuronectes quadrituberculatus*), turbot (*Scophthalmus maximus*) [45]. In the current study, the amount of gonad DHA was determined higher than the amount of fillet DHA in the breeding period. The gonad EPA rates were higher than the fillet EPA rates. In a study in which fatty acid values were determined in many marine fish species, DHA+EPA was 13% in spotted flounder (*Lepidorhombus boscii*) [46]. The current study showed very high values of DHA+EPA ratios ranging from 22.20% to 31.38%. Fish need PUFA to adapt to lower water temperatures, and cold sea fish are richer in n-3 fatty acids [47]. EFSA [48] recommended that a daily intake of 250-500 mg/100g EPA and DHA is appropriate against the risk of cardiovascular disease. Rimm et al. [49] reported that the amount of n-3 in flounder fillet is 350 mg/100 g. In the current study, however, the amount of n-3 in flounder was determined to be quite high, and this species met the daily EPA and DHA intake recommended by EFSA [48] in both the egg and the fillet. Soriguer et al. [50] found that the DHA level in a sole fish sample taken from the southern coast of Spain was 14.8 (%total lipid). In another study, Riley [51] determined the percentages of DHA and EPA for the tongue base as 14.4 and 7.3, respectively. Soriguer et al. [50] found that the DHA level in a sole sample taken from the southern coast of Spain was 14.8 (%total lipid). In another study, Riley [51] determined the percentages of DHA and EPA for the sole fish as 14.4 and 7.3, respectively.

The n-3/n-6 ratio is a good index to compare the relative nutritional value of fish oil [52]. A high n3/n6 ratio is required to reduce the risks of coronary heart disease, plasma lipid levels and cancer [40]. In addition, rational intake of n3/n6 fatty acids in human diets has been associated with the prevalence of coronary heart disease [12]. While people in the Western world consume the n3/n6 ratio around 1:15-20, the recommended intake is 1:6 [53]. It is recommended that the n3/n6 ratio be above 1. In a study in which fatty acid values were determined in many marine fish species, the n3/n6 ratio was reported as 3.4% in spotted flounder [46]. In the current study, the n3/n6 ratio was determined at lower levels in the fillet than in the gonad.

Various fatty acid ratios and some nutritional indices have been put forward to determine the health quality of lipids in foods used for human consumption. It is recommended that the PUFA/SFA ratio in foods should be above 0.45 in human diets [54]. Low PUFA/SFA ratios may increase the risk of cardiovascular diseases. The PUFA/SFA ratio of the diets obtained in the current study was quite high (fillet and gonad, 1.25 and 1.39, respectively). This shows that flounder is suitable for human consumption in terms of PUFA/SFA (Figure 2).

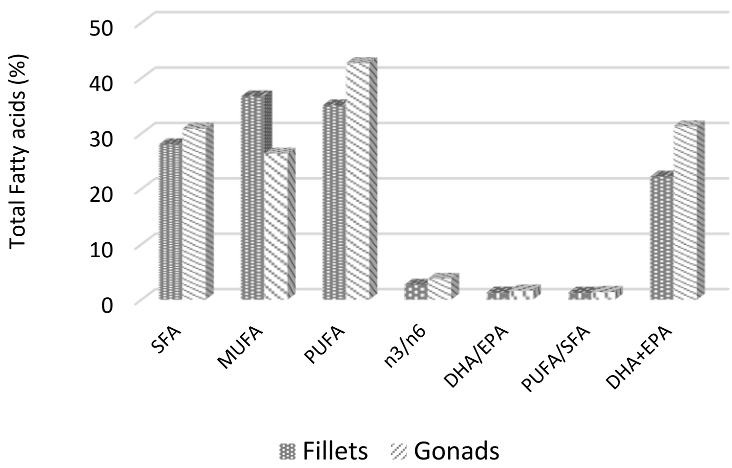

Figure 2. Variations in the total fatty acids of the European flounder (*Platichthys flesus)* fillet and the gonads

In the present study, no difference was determined between the nutritional quality indices IT and h/H in the gonads and fillets of European flounder (P>0.05). The IA value was higher in fillets than in gonads (P<0.05). FLQ value was determined to be significantly higher in gonads than in fillets (P<0.05; Table 3).

Table 3. *The nutritional quality indices of the gonad and fillets of the European flounder (Platichthys flesus)*

	Gonads	Fillets
IA	$0.51±0.01^{a}$	$0.54±0.05^{b}$
IT	$0.57±0.04^{a}$	$0.54±0.01^{a}$
FLQ	$31.30±1.73^{a}$	$22.89±1.09^{b}$
h/H	$2.44±0.36^{a}$	$2.41±0.01^{a}$

Data are mean ±SD. Means with different superscript letter in a row are significantly different (p>0.05 IA: The index of atherogenicity, IT: The index of thrombogenicity, FLQ: Flesh lipid quality, h/H: hypocholesterolemic/hypercholesterolemic.

A healthy animal product can be characterized by low AI and IT and high FLQ and h/H index [3-55-25]. AI and IT show the potential to stimulate platelet aggregation [56]. Because IT tends to form clots in blood vessels, this is defined as the relationship between saturated and unsaturated fatty acids. Therefore, the smaller the AI and IT values, the greater the potential to protect against coronary artery disease. In addition, it has been reported that fatty acids can reduce cholesterol and phospholipid levels in the blood and thus prevent the emergence of micro and macro coronary diseases [57]. In fish diets, AI and TI are recommended to be below 1.0 and 0.5, respectively, in terms of human health [58]. In the current study, AI and IT values were determined below 1.0 and 0.5. SFA, MUFA and n-6 PUFA are TI and AI. It has been reported that these lipid indices have potential effects on diet quality and coronary artery diseases [59-60].

hypocholesterolemic/Hypercholesterolemic index (h/H) characterizes the relationship between hypocholesterolemic fatty acid and hypercholesterolemic fatty acid. Compared with the PUFA/SFA ratio, the h/H ratio may more accurately reflect the effect of fatty acid composition on the prevention of cardiovascular disease (CVD). The h/H has certain limitations. h/H may contain more types of fatty acids, such as other molecular types of MUFA, and different weights may be assigned to different types of molecular fatty acids. Some studies reported that the h/H value is between 1.73 and 4.75 for shellfish, excluding *Loxechinus albus* [61] and between 1.54 and 4.83 for fish, excluding *Opisthonema oglinum*, which is 0.87 [58]. The h/H is related to the effect of specific fatty acids on cholesterol metabolism, and higher values are considered more desirable for human health [62]. Rincón-Cervera et al. [61] reported the highest h/H value among all analyzed fish species was in red cusk-eel (*Genypterus chilensis*, 2.93), followed by Chilean hake (Merluccius gayi gayi, 2.23), while the fish with the lowest h/H values were Chilean sand bass (*Pinguipes chilensis*, 1.54) and jack mackerel (*Trachurus murphyi*, 1.73). Recent studies have reported h/H values between 0.65 and 2.46 for fish lipids [63-58]. In the present study, the h/H value was determined 2.44 and 2.41 for the gonad and fillet, respectively.

The lipid quality of meat is directly related to EPA and DHA ratios. The FLQ value represents the ratio of EPA+DHA to fatty acids. Omega-3 fatty acids are beneficial for both healthy people and those suffering from cardiovascular diseases and are reported to reduce the risk of arrhythmias (abnormal heartbeats), which can lead to sudden death [64]. Łuczyńska et al. [65] reported an FLQ value of 20.25 for *Platichthys flesus*. In the present study, relatively high FLQ values (29.59-33.02 for gonads; 23.17-21.34 for fillets) were obtained. In this context, it can be said that European flounder has a good nutritional quality for human consumption.

4. Conclusion

Based on the data obtained from this study, it has been suggested that the European flounder is an exceptionally nutritious fish species in terms of its biochemical content, fatty acid composition, and overall nutritional quality. The n3/n6 fatty acid ratio in the human diet is crucial for visualizing heart disease and reducing cancer risk by lowering plasma lipid levels [40]. Therefore, increasing the consumption of n3 fatty acids is important for promoting human health [66]. In this study, both the gonads and fillets of the evaluated European flounder were characterized by low-fat content and high levels of n-3 fatty acids, particularly EPA and DHA. Interestingly, the EPA+DHA content was found to be higher in the gonads compared to the fillets. This indicates that the gonads are a richer source of these beneficial fatty acids. According to the values of PUFA, the totals of EPA and DHA, the n-3/n-6 ratios, and the nutritional quality index values, the European flounder—both in its gonads and fillets—has been determined to be an important source of essential fatty acids. This makes it a valuable addition to the diet for those looking to improve their intake of n-3 fatty acids and thereby enhance their overall health and well-being.

Conflict of interest

The Author reports no conflict of interest relevant to this article

Research and publication ethics statement

The author declares that this study complies with research and publication ethics.

References

[1] Dernekbaşı, S., Karataş, E., and Karayücel, İ. (2022). Comparative analysis of proximate and fatty acid composition and mineral matter contents of cultured rainbow trouts (*Oncorhynchus mykiss*) in different farms. *Gaziosmanpasa Journal of Scientific Research,* 11(2), 123-134.

[2] Ahern, M., Thilsted, S. H., Oenema, S., Barange, M., Cartmill, M. K., Brandstrup, S. C., and Zhou, X. (2021). The role of aquatic foods in sustainable healthy diets. UN Nutrition. 64 pp.

[3] Wołoszyn, J., Haraf, G., Okruszek, A., Werenska, M., Goluch, Z., and Teleszko, M. (2020). Fatty acid profiles and health lipid indices in the breast muscles of local Polish goose varieties, *Processing and Products,* 99, 1216–1224.

[4] Özer, Ö., Karakaya, S., and El S.N. (2022). Indexes evaluate the nutritional properties of foods. *The Journal of Food,* 47(1), 78-90.

[5] Oluwaniyi, O. O., Dosumu, O.O., and Awolola, G. V. 2010. Effect of local processing methods (boiling, frying and roasting) on the amino acid composition of four marine fishes commonly consumed in Nigeria. *Food Chemistry,* 123(4), 1000-1006.

[6] Gorga, C. (1998). A new selected comments on lipids. Quality Assurance of Seafood Appendix 1, 245 p.

[7] Nettleton, J. A. (2000). Seafood nutrition in the 1990's issues for the consumer, Seafood Science and Technology, chapter 4, Ed. By Graham Bligh Canadian. *Inst. of Fish Tech.,* 32-39 pp.

[8] FAO/WHO. (2011). Joint FAO/WHO expert consultation on the risks and benefits of fish consumption (Rome, World Health Organization, Trans.).

[9] European Food Safety Authority (EFSA) (2014). Scientific opinion on health benefits of seafood (fish and shellfish) consumption in relation to health risks associated with exposure to methylmercury. *EFSA Journal,* 12(7), 3761, 80 pp.

[10] Harris, W.S., and von Shacky, M.D.C. (2004). The Omega-3 Index: A new risk factor for death from coronary heartdisease? *Prev Med.,* 39, 212-220.

[11] Keskin, İ., Köstekli, B., and Erdem, M.E. (2022). Comparison of nutrient content and fatty acid composition of sold Turkish salmonin the Central Black Sea Region with Atlantic salmon, *Academic Journal of Meat and Milk Board,* 3, 18-25.

[12] Coultate, T. (2016). Food The chemistry of its components. Royal Society of Chemistry, 6st edition, ISBN 9781849738804

[13] Gökçe, M.A., Taşbozan, O., Çelik, M., and Tabakoğlu, S. (2004). Seasonal variations in proximate and fatty acid compositions of female common sole (*Solea solea*). *Food Chemistry,* 88(3), 419–423.

[14] Ruff, N., Fitzgerald, R.D., Cross, T.F., and Kerry, J.P. (2002). Comparative composition and shelflife of fillets of wild and cultured turbot (*Scophthalmus maximus*) and Atlantic halibut (*Hippoglossus hippoglossus*). *Aquaculture International,* 10(3), 241–256.

[15] Martinez, B., Miranda, J.M., Nebot, C., Rodriguez, J.L., Cepeda, A., and Franco. C. M. (2010). Differentiation of farmed and wild turbot (*Psetta maxima*): proximate chemical composition, fatty acid profile, trace minerals and antimicrobial resistance of contaminant bacteria. *Food Sci Technol Int,* 16(5), 435–41.

[16] Colakoglu, F.A., Ormanci, H.B., and Cakir, F. (2011). Effect of marination and smoking on lipid and fatty acid composition of thornback ray (*Raja clavata*) and spiny dogfish (*Squalis acanthias). European food research & technology,* 232(6), 1069–1075.

[17] Karl, H., Manthey-Karl, M., Ostermeyer, U., Lehmann, I., and Wagner, H. (2013). Nutritional composition and sensory attributes of Alaskan flatfishes compared to plaice (*Pleuronectes platessa*). *International Journal of Food Science and Technology,* 48 (5), 962–971.

[18] Afonso, C., Cardoso, C., Lourenço, H. M., Anacleto, P., Bandarra, N. M., Carvalho, M. L., Castro, M., and Nunes, M. L. (2013). Evaluation of hazards and benefits associated with the consumption of six fish species from the Portuguese coast. *Journal of Food Composition and Analysis,* 32(1), 59–67.

[19] Barbosa, R.G., Trigo, M., Prego, R., Fett, R., and Aubourg, S.P. (2018). The chemical composition of different edible locations (central and edge muscles) of flat fish (*Lepidorhombus whiffiagonis*). *International Journal of Food Science & Technology,* 53(2), 271–281.

[20] Aidos, I., van der Padt, A., Luten, J. B., Boom, R. M. (2002). Seasonal changes in crude and lipid composition of herring fillets, byproducts, and respective produced oils. *Journal of Agricultural and Food Chemistry,* 50(16), 4589–4599.

[21] Küçükgülmez, A., Celik, M., Ersoy, B., and Yanar, Y. (2010). Effects of season on proximate and fatty acid compositions of two mediterranean fish - the round herring (*Etrumeus teres*) and tub gurnard (*Chelidonichthys lucernus*). *International Journal of Food Science & Technology,* 45(5), 1056–1060.

[22] Mateos, H.T., Lewandowski, P.A., and Su, X.Q. (2010). Seasonal variations of total lipid and fatty acid contents in muscle, gonad and digestive glands of farmed Jade Tiger hybrid abalone in Australia. *Food Chemistry,* 123(2), 436–441.

[23] AOAC. (1995). Official methods of analysis of the AOAC. In Association of Official Agricultural Chemistry, 17th ed.; Association of Official Analytical Chemists: Arlington, VA, USA, 2000.

[24] Hanson, S.W.F., and Olley, J. (1963). Application of the Bligh and Dyer method of lipid extraction to tissue homogenates. *Biochemical Journa,* 89, 101–102.

[25] Garaffo, M., Agius, R., Nengas, Y., Lembo, E., Rando, R., Maisano, R., Dugo, G., and Giuffrida, D. (2011). Fatty acids profile, atherogenic (IA) and thrombogenic (IT) health lipid indices, of raw roe of Blue Fin Tuna (*Thunnus thynnus* L.) and their salted product "Bottarga". *Food and Nutrition Sciences,* 2, 736–743.

[26] Yu, J., Li, S., Chang, J., Niu, H., Hu, Z., and Han, Y. (2018). Effect of variation in the dietary ratio of linseed oil to fish oil on growth, body composition, tissues fatty acid composition, flesh nutritional value and immune indices in Manchurian trout, *Brachymystax lenok*. Aquac. *Nutr.*, 1–11.

[27] Dernekbaşı, S., and Karayücel,I. (2021). Effect of alternate feeding with fish oil- and peanut oil-based diets on the growth and fatty acid compositions of European seabass fingerlings (*Dicentrarchus labrax*) in the recirculated systems. *Aquac. Res.*, 52(7), 3137-3147.

[28] Kendler S., Tsoukalas D., Jakobsen A.N., Zhang J., Alexandros G., Asimakopoulos A.G., and Lerfall, J. (2023). Seasonal variation in chemical composition and contaminants in European plaice (*Pleuronectes platessa*) originated from the west-coast of Norway. *Food Chemistry,* 401, 134-155.

[29] Lunn, J., and Theobald, H.E. (2006). The health effects of dietary unsaturated fatty acids. Nutrition Bulletin, 31(3): 178-224.

[30] Fung, T.T., Rexrode, K.M., Mantzoros, C.S., Manson, J.E., Willett, W.C., and Hu, F.B. (2009). Mediterranean diet and incidence and mortality of coronary heart disease and stroke in women. *Circulation,* 119(8), 1093-1100.

[31] Hellberg, R.S, DeWitt, C.A.M., and Morrissey, M.T(2012). Risk-benefit analysis of seafood consumption: a review. *Comprehensive Reviews in Food Science and Food Safety,* 11(5), 490-517.

[32] Saoud, P.I., Batal, M., Ghanawi, J., and Lebbos, N. (2008). Seasonal evaluation of nutritional benefits of two fish species in the eastern Mediterranean Sea. *International Journal of Food Science & Technology,* 43(3), 538-542.

[33] Horn, S.S., Ruyter, B., Meuwissen, T.H., Hillestad, B., and Sonesson, A.K. (2018). Genetic effects of fatty acid composition in muscle of Atlantic salmon. *Genetics Selection Evolution,* 50(1), 23.

[34] Kaçar S., Kaya H., and Başhan M. (2021). Dişi *Salmo trutta magrostigma* (Dumeril, 1858)'nın kas dokusu yağ içeriğinin mevsimsel değişimi. *Int. J. Pure Appl. Sci.,* 7(3), 356-363.

[35] Thornes, F.W. (2022). Chemical and nutritional investigation of four little utilized fish species caught on the coast of Mid-Norway. Master's thesis in Food science, sustainability and technology. Norwegian University of Science and Technology Faculty of Natural Sciences Department of Biotechnology and Food Science. 65 pages. Norwegian.

[36] Prato, E., and Biandolino, F. (2012). Total lipid content and fatty acid composition of commercially important fish species from the Mediterranean Mar Grande Sea. *Food Chemistry*, 131, 1233-1239

[37] Turchini, G.M., and Francis, D.S. (2007). A whole body, in vivo, fatty acid balance method to quantify PUFA metabolism (Desaturation, Elongation and Beta-oxidation). *Lipids,* 42, 1065-1071.

[38] Higgs, D.A., Dosanjh, B.S., Plotnikoff, M.D., Markert, J.R., Lawseth, D., McBride, J.R. and Buckley, J.T., (1992). Influence of dietary protein to lipid ratio and lipid composition on the perfor-

mance and marine survival of hatchery reared chinook salmon (*Oncorhynchus tshawytscha*). *Bulletin of the Aquaculture Association of Canada,* 92(3), 46–48.

[39] Pickova, J., Dutta, P.C., Larsson, P.-O., and Kiessling, A. (1997). Early embryonic cleavage pattern, hatching success, and egg-lipid fatty acid composition: comparison between two cod (*Gadus morhua*) stocks. *Can. J. Fish. Aquat. Sci.,* 54, 2410–2416.

[40] Kinsella, J.E., Broughton, K.S., and Whelan, J.W. (1990). Dietary unsaturated fatty acids: interactions and possible needs in relation to eicosanoid synthesis. *The Journal of Nutritional Biochemistry,* 1(3), 123-141.

[41] Ozogul, Y., and Ozogul F. (2007). Fatty acid profiles of commercially important fish species from the Mediterranean. *Aegean and Black Seas Food Chemistry,* 100, 1634-1638.

[42] Özogul, Y., Özogul, F., Çiçek, E., Polat, A., and Kuley, E. (2009). Fat content and fatty acid compositions of 34 marine water fish species from the Mediterranean Sea. *International Journal of Food Sciences and Nutrition,* 60(6), 464-475.

[43] Connor, W.E. (2000). Importance of n-3 fatty acids in health and disease. *Am. J. Clin. Nutr.,* 17(1), 171S-175S.

[44] Lavens, P., Leregue, E., Jaunet, H., Brunel, A., Dhert, Ph., and Sorgeloos, P. (1999). Effect of dietary essential fatty acids and vitamins on egg quality in turbot broodstocks. *Aquacult. Int.,* 7, 225-240.

[45] Kris-Etherton, PM., Hu, FB., Ros, E., and Sabate, J. (2007). The role of tree nuts and peanuts in the prevention of coronary heart disease: Multiple Potential Mechanisms. *The Journal of Nutrition,* 138(9), 1746S–1751S.

[46] Passi, S., Cataudella, S., Marco, P., Simone, F., and Rastrelli L. (2002). Fatty acid composition and antioxidant levels in muscle tissue of different mediterranean marine species of fish and shellfish. *J. Agric. Food Chemistry,* 50, 7314-7322.

[47] Chanmugam, P., Boudreau, M., and Hwang, D.H. (1986). Differences in the ω3 fatty acid contents in pond-reared and wild fish and shellfish. *Journal of Food Science,* 51(6), 1556-1557.

[48] European Food Safety Authority (EFSA) (2012). Scientific opinion on the tolerable upper intake level of eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and docosapentaenoic acid (DPA). *EFSA Journal,* 10(7), 2815, 48 pp.

[49] Rimm, E.B., Appel, L.J., Chiuve, S.e., Engler, M.B., Kris-Etherton, P.M., Mozaffarian, D., Siscovick, D.S., and Lichtenstein, A.H. (2018). Seafood long-chain n-3 polyunsaturated fatty acids and cardiovascular disease. *Circulation,* 138, e35–e47.

[50] Soriguer, F., Serna, S., Valverde, E., Hernando, J., Martin-reyes, A., Soriguer, M., Pareja, A., Tinahones, F., and Esteva, I. (1997). Lipid, protein and calorific content of different Atlantic and Mediterranean fish, shellfish and mollusc commonly eaten in south of Spain. *European Journal of Epidemiology*, 13, 451-463

[51] Riley WA, Evans GW, Sharrett AR, Burke GL, and Barnes RW. Variation of common carotid artery elasticity with intimal-medial thickness: the ARIC Study: Atherosclerosis Risk in Communities. *Ultrasound Med Biol.*, 23, 157–164.

[52] Piggott, G.M., and Tucker, B.W. (1990). Effects of technology on nutrition Marcel Dekker, New York.

[53] Wijendran, V., and Hayes, K.C. (2004). Dietary n-6 and n-3 fatty acid balance and cardiovascular health. *Annual Review of Nutrition*, 24, 597-615.

[54] Chen, Z., Xu, Y., Liu, T., Zhang, L., Liu, H., and Guan, H. (2016) Comparative studies on the characteristic fatty acid profiles of four different Chinese medicinal Sargassum seaweeds by GC-MS and chemometrics. *Mar. Drugs*, 14, 68.

[55] Zorlu, K., and Gümüş, E. (2022). Effect of dietary fish oil replacement with grape seed oil on growth performance, feed utilization and fatty acid profile of mirror carp, *Cyprinus carpio*, fingerlings. *Aquac. Res.*, 53, 1755–1765.

[56] Ghaeni, M., Ghahfarokhi, K.N., and Zaheri, L. (2013). Fatty acis profile, atherogenic (IA) mand Thrombogenic (IT) health lipid indices in *Leiognathus bindus* and *Upeneus sulphureus*. *J. Mar. Sci. Res. Dev.*, 3, 4.

[57] Turan, H., Kaya, Y., and Sönmez, G. (2006). Balık etinin besin değeri ve insan sağlığındaki yeri. E.U. *J. of Fish. Aquat. Sci.*, 23(1/3), 505–508.

[58] Fernandes, C.E., Vasconcelos, M.A., Ribeiro, M.A., Sarubbo, L.A., Andrade, S.A., and Filho, A.B. (2014). Nutritional and lipid profiles in marine fish species from Brazil. *Food Chem.*, 160, 67–71.

[59] Jankowska, E.A., Rozentryt, P., Witkowska, A., Nowak, J., Hartmann, O., Ponikowska, B., and McMurray, J.J. (2010). Iron deficiency: an ominous sign in patients with systolic chronic heart failure. *European Heart Journal*, 31(15), 1872-1880.

[60 Görgün, S., and Zengin, G. (2015). Determination of fatty acid profiles and esterase activities in the gills and gonads of *Vimba vimba* (L. 1758). *Journal of the American Oil Chemists' Society*, 92(3), 353-360.

[61] Rincón-Cervera, M.Á., González-Barriga, V., Romero, J., Rojas, R., and López-Arana, S. (2020). Quantification and distribution of omega-3 fatty acids in south pacific fish and shellfish species. *Foods*, 9, 233.

[62] Chen, D.W., and Zhang, M. (2007). Non–volatile taste active compounds in the meat of Chinese mitten crab (Eriocheir sinensis), *Food Chemistry*, 104, 1200–1205.

[63] Zhang, X., Ning, X., He, X., Sun, X., Yu, X., Cheng, Y., Yu, R.Q., and Wu, Y. (2020). Fatty acid composition analyses of commercially important fish species from the Pearl River Estuary, China. *PLoS ONE*, 15, e0228276.

[64] URL 2. 2016. http://www.heart.org/HEARTORG/HealthyLivin g/HealthyEating/ Healthy Diet Goals/Fishand- Omega-3-Fatty Acids_UCM_303248_Article.jsp#.Wjtw499l- M8, (19.12.2017). In: Dagtekin, B.B.G., Misir, G.B., Kutlu, S., Basturk, O. 2017. *Med. Fish. and Aquac. Res.* 1(1), 2-14.

[65] Łuczyńska, J., Paszczyk, B., and Łuczyński, M.J. (2014). Fatty acid profiles in marine and freshwater fish from fish markets in northeastern Poland. *Arch. Pol. Fish.* 22, 181-188.

[66] Simopoulos, A.P. (2002). Omega-3 fatty acids and cardiovascular disease: the epidemiological evidence. *Environmental Health and Preventive Medicine,* 6(4), 203-209.