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Seasonal Differences in The Total Fatty Acid Profile of 6 Fish Species from The Marmara Sea

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ABSTRACT

Seasonal differences in the fatty acid profiles of *Engraulis encrasicolus* (anchovy), *Mullus surmuletus* (striped red mullet), *Trachurus trachurus* (horse mackerel), *Pomatomus saltator* (bluefish), *Dicentrarchus labrax* (European seabass), *Sardina pilchardus* (European pilchard) captured from Marmara Sea, have been looked into. In all sampling seasons, the major fatty acids of fish have been palmitic acid (C16:0), docosahexaenoic acid (DHA, C22:6), oleic acid (C18:1), eicosapentaenoic acid (EPA C20:5) and palmitoleic acid (C16:1). The contents of C20:5 n-3 and C22:6 n-6 in the marine fish have ranged from 1.31% to 8.13% of total fatty acid, and from 1.47% to 16.44%, respectively. This study has shown that fish species were rich in n-3 PUFA, especially, docosahexaenoic acid and eicosapentaenoic acid and we have concluded that seawater fish were a good source for DHA and EPA. n3/n6 rates in *E. encrasicolus, M. surmuletus, T. trachurus, P. saltator, D. labrax, S. pilchardus*, were 3.80-3.44, 2.09-1.06, 4.22-2.80, 2.22-1.49, 0.79-0.43, 1.85-0.81, in spring and autumn, respectively.

Keywords: Fish, Muscle, Fatty acid profile, Seasonal differences

Marmara Denizi'nden 6 Balık Türünün Toplam Yağ Asidi Profilindeki Mevsimsel Farklılıklar

ÖZ

Marmara Denizi'nden yakalanan *Engraulis encrasicolus* (hamsi), *Mullus surmuletus* (tekir), *Trachurus trachurus* (istavrit), *Pomatomus saltator* (lüfer), *Dicentrarchus labrax* (Avrupa deniz levreği), *Sardina pilchardus* (sardalya)'un yağ asidi kompozisyonlarındaki mevsimsel değişiklikler araştırılmıştır. Tüm örnekleme mevsimlerinde, balıkların başlıca yağ asitleri palmitik asit (C16:0), dokosaheksaenoik asit (DHA C22:6), oleik asit (C18:1), eikosapentaenoik asit (EPA C20:5) ve palmitoleik asitdir (C16:1). Deniz balığındaki C20:5 n-3 ve C22:6 n-6 içeriği toplam yağ asidinin sırasıyla % 1.31 ile % 8.13'ü ve % 1.47 ile % 16.44'ünü oluşturmaktadır. Bu çalışmanın sonuçları, bu balık türlerinin n-3 PUFA açısından zengin olduğunu, özellikle de eikosapentaenoik asit ve dokosaheksaenoik asitten zengin olduğunu göstermektedir ve biz deniz balıklarının, EPA ve DHA için iyi bir kaynak olduğu sonucuna vardık. *E. encrasicolus*, *M. surmuletus*, *T. trachurus*, *P. saltator*, *D. labrax*, *S. pilchardus*'daki n3 / n6 oranları, ilkbahar ve sonbahar aylarında sırasıyla 3.80-3.44, 2.09-1.06, 4.22-2.80, 2.22-1.49, 0.79-0.43, 1.85-0.81'dır.

Anahtar kelimeler: Balık, Kas, Yağ asidi profili, Mevsimsel farklılıklar.

1. Introduction

The fish fats contain PUFA such as DHA and EPA that cannot be synthesized in the human body (Connor, 2000; Glogowski and Ciereszko 2001). DHA is basic for normal

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fetal brain and cognitive development as the formation of neuron synapses in the brain depends strongly on the integration of this fatty acid into growing neurons (Jensen, 2006). Consuming fish once a week decreases vulnerability to ventricular fibrillation and reduces coronary heart disease risk (Bang et al., 1980). The fats are also needed in diets for regulating body cholesterol metabolism and for absorbing fat-soluble vitamins A, E, K and D from nutrient (Connor, 2000; Kris Etherton et al., 2003). Essential fatty acids, such as (C18:3n-3) linolenic acid and linoleic acid (C18:2n-6) are of great physiological significance. Linoleic and linolenic acids either accumulate in the adipose tissues or oxidize or are converted into long-chain greatly unsaturated fatty acids such as DHA, EPA and AA, via fatty acid elongation and desaturation steps at the microsomal level (Cook, 1996; Ozogul et al., 2009).

Fatty acid combination of fish and the fat content are not stable (Zlatanos and Laskaridis, 2007). Variations in lipid and fatty acid compositions between and within fish species, depending on factors such as food availability, age, water salinity, location, diet, sex and the season have been well reported by numerous authors (Shearer, 1994; Steffens, 1997; Gorgun and Akpinar, 2007; Akpinar et al., 2009). In general, a decrease in temperature causes an increase in the level of unsaturation (Henderson and Tocher, 1987).

The purpose of this research has been to detect fatty acid profiles and the lipid content of 6 marine fish species from the Marmara Sea.

2. Materials and Methods

Fish samples investigated in this study have been taken from the Marmara Sea for two seasons (spring and autumn) for analysis and investigation. Fish were caught by the local fishermen in the middle of March and October for each season during 2014-2015 and gender differences were not taken into account. Fish samples have been carried to the laboratories in the fillet in frozen form and again frozen environment. At the beginning of each analysis, the fillets have been homogenized in the mixture of chloroform/methanol (2:1, v/v) using an Ultra-Turrax T25 homogenizer by Folch et al., (1957) method transesterified with BF3 methanol (Moss et al., 1974).

The resultant mixture of fatty acid methyl esters in hexane/chloroform have been analyzed by using a HP Agilent 6890N model gas chromatograph. Capillary column has been used. Helium has been used as carrier gas. Data have been expressed as FID response area with relative percent. Each reported datum has been presented as an average of three results obtained by GC analyses.

3. Results and Discussion

Table 1 shows a range of fat content of seawater species. The lipid contents of seawater species have been between 3.47% (*T. trachurus* in spring) to 14.93% (*P. saltator in autumn)*.

Table 1. Total lipid percent of fish (% of lipid)

Species	Spring (%)	Autumn (%)
Dicentrarchus labrax	3.88	4.16
Engraulis encrasicolus	6.5	7.22
Mullus surmuletus	10.81	11.37
Pomatomus saltator	6.65	14.93
Sardina pilchardus	9.27	8.07
Trachurus trachurus	3.47	8.0

Table 2 indicates fatty acid compositions of muscle of *P. saltator*, *M. surmuletus*, *S. pilchardus*, *T. trachurus*, *D. labrax* and *E. encrasicolus* from the Marmara Sea in Turkey. The lipid content of fish changes due to geographical origin, species, season, diet and gender (Rasoarahona et al., 2005). *P. saltator*, *M. surmuletus*, *S. pilchardus*, *T. trachurus* have been measured to have the high-fat (>8%) (Sigurgisladottir and Palmadottir, 1993). Fatty acid compositions of sea water fish species for myristic acid (C14:0), palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1), docosahexaenoic acid (DHA C22:6) have been ranged between 0.20 and 0.27%, 20.40 and 26.83%, 0.20 and 0.49%, 23.31 and 45.43%, 2.17 and 19.22%, respectively. In the same work, during March, it has been found that oleic acid was 23.31% in striped red mullet, 37.90% in *P. saltator*, 28.66% in *D. labrax*, and docosahexaenoic acid (C22:6) has been found 16.93% in *M. surmuletus*, 7.34% in *P. saltator*, 7.40% in *D. labrax*. As the results of the same research, it has been reported that palmitic acid has been found to be 21.59% in M. surmuletus, 26.83% in P. saltator and 20.40% in D. labrax. It has also been reported that ratios for SFAs, MUFAs and PUFAs have been found to be 25.47%, 42.66%, 31.85% in M. surmuletus, to be 28.78%, 48.32% and 22.91% in P. saltator, to be 22.66%, 44.61% and 32.62% in D. labrax, respectively (Abouel-Yazeed, 2013). In the present work, we have found that SFAs, MUFAs and PUFAs have been 33.82%, 45.91% and 19.90% in M. surmuletus, to be 36.95%, 40.37% and 22.24% in P. saltator, 26.58%, 39.33% and 33.92% in D. labrax, respectively, in spring season.

Table 2. Seasonal variations in total fatty acid composition of muscle of *P. saltator, M. surmuletus, S. pilchardus, T. trachurus, D. labrax* and *E. encrasicolus* from the Marmara Sea (% of total FA)

	(*Pomatomus saltator*)		**(*Dicentrarchus labrax*)**		**(*Sardina pilchardus*)**	
	Spring	**Autumn**	**Spring**	**Autumn**	**Spring**	**Autumn**
Fatty acids	**Means±S.D.**	**Means±S.D.**	**Means±S.D.**	**Means±S.D.**	**Means±S.D.**	**Means±S.D.**
C8:0	----	0.01±0.00a	-----	----	0.01±0.00a	0.01±0.01a
C10:0	0.06±0.08a*	0.01±0.00b	----	----	0.03±0.02a	0.05±0.00a
C12:0	0.03±0.00a[§]	0.05±0.00b	0.03±0.00a	----	0.04±0.01a	0.20±0.00b
C13:0	0.025±0.01a	0.02±0.01a	-----	----	0.03±0.01a	0.02±0.00b
C14:0	4.40±0.16a	5.54±0.11b	1.70±0.23a	2.10±0.14b	5.07±0.85a	3.73±0.03b
C15:0	0.66±0.04a	0.60±0.01a	0.20±0.02a	0.22±0.01a	0.48±0.40a	0.53±0.01a
C16:0	20.27±0.36a	22.67±0.46b	17.71±0,92a	17.99±0.83a	19.84±0.03a	17.99±0.16b
C17:0	1.39±0.05a	1.32±0.33a	0.39±0.05a	0.43±0.07a	1.26±0.01a	1.17±0.01a
C18:0	7.72±0.15a	7.61±0.12a	4.73±0.25a	5.06±0.49a	5.82±0.77a	6.37±0.04a
C20:0	0.85±0.13a	0.75±0.02a	0.86±0.49a	0.36±0.03b	0.66±0.15a	0.83±0.02a
C21:0	0.82±0.20a	0.82±0.02a	0.59±0.12a	1.04±0.17b	1.30±0.35a	2.01±0.01b
C22:0	0.44±0.18a	0.51±0.10a	0.23±0.01a	0.52±0.15b	0.59±0.23a	0.36±0.01b
C24:0	0.31±0.03a	0.55±0.13a	0.17±0.09a	0.41±0.16b	0.25±0.06a	0.09±0.13b
∑SFA	**36.95±0.34**	**40.44±0.48**	**26.58±1.48**	**28.13±0.87**	**35.35±1.29**	**33.35±0.08**
C14:1 ω5	0.11±0.02a	0.09±0.00a	0.045±0.01a	0.035±0.01a	0.18±0.03a	0.07±0.00a
C15:1 ω5	0.15±0.03a	0.13±0.01a	0.14±0.02a	0.08±0.00b	0.19±0.01a	0,07±0.00a
C16:1 ω7	7.07±0.13a	11.80±0.54b	4.04±0.05a	4.18±0.20b	10.03±0.23a	2.19±1.46b
C17:1 ω8	1.02±0.02a	1.16±0.58a	0.40±0.20a	0.42±0.05a	1.17±0.04a	0.63±0.01b
C18:1 ω9	27.76±0.77a	21.20±0.44a	31.41±2.12a	33.76±1.17a	25.81±0.04a	34.44±0.38b
C20:1 ω9	3.39±0.12a	1.29±0.02b	3.00±0.05a	3.13±0.23a	3.75±0.03a	4.00±0.01a
C22:1 ω9	0.64±0.07a	0.07±0.04b	-----	----	0.88±0.02a	------
C24:1 ω9	0.24±0.04a	0.28±0.09a	0.31±0.05a	1.55±0.51b	1.19±1.82a	0.14±0.11b
∑MUFA	**40.37±0.54**	**36.01±0.24**	**39.33±2.35**	**43.09±1.05**	**43.20±1.56**	**41.54±1.26**
C18:2 ω6	2.17±0.14a	6.13±0.17b	18.11±0.96	15.51±0.58	1.91±0.29a	10.84±0.30a
C18:3 ω6	0.26±0.08a	0.16±0.02a	0.34±0.04a	----	0.21±0.03a	0.26±0.02a

C18:3 ω3	0.46±0.05a	0.89±0.02b	2.16±0.32a	2.00±0.16a	0.75±0.04a	0.60±0.02a
C20:2 ω6	0.50±0.07a	0.67±0.16b	1.41±0.07a	1.88±0.28b	0.46±0.04a	0.92±0.06b
C20:3 ω6	0.51±0.10a	0.51±0.10a	0.23±0.01a	0.52±0.15b	0.70±0.04a	0.36±0.01b
C20:3 ω3	0.59±0.07a	0.76±0.21b	0.16±0.02a	0.50±0.17b	0.33±0.02a	0.77±0.23b
C20:4 ω6	3.31±0.09a	1.88±0.15b	2.06±0.67a	1.78±0.25a	4.21±0.05a	0.86±0.12b
C20:5 ω3	2.57±0.08a	4.21±0.21a	2.89±0.48a	2.47±0.23a	3.25±0.02a	2.12±0.04b
C22:2 ω6	0.06±0.02a	----	0.035±0.01a	----	0.11±0.01a	0.18±0.27a
C22:5 ω3	1.91±0.40a	----	-----	----	---	-----
C22:6 ω3	10.54±0.08a	8.20±0.30a	6.65±0.64a	3.53±0.38b	10.05±0.71a	7.47±0.53b
∑PUFA	**22.24±1.41**	**23.40±1.19**	**33.92±0.61**	**28.19±1.10**	**21.97±0.61**	**24.38±0.80**
∑ ω3	15.42	14.06	11.85	8.50	14.37	10.96
∑ ω6	6.96	9.46	22.21	19.72	7.79	13.49
ω3/ ω6	**2.22**	**1.49**	**0.79**	**0.43**	**1.85**	**0.81**

*Values reported are means±S.D.

§ Average of three lots analysed.

[abc]Values for each sample with different superscript letters in the same fraction are significantly different at $p<0.05$.

Table 2 continued.

	(*Engraulis encrasicolus*)		(*Mullus surmuletus*)		(*Trachurus trachurus*)	
	Spring	**Autumn**	**Spring**	**Autumn**	**Spring**	**Autumn**
Fatty acids	**Means±S.D.**	**Means±S.D.**	**Means±S.D.**	**Means±S.D.**	**Means±S.D.**	**Means±S.D.**
C8:0	0.05±0.02a*	0.03±0.02a	----	-----	-----	-------
C10:0	0.05±0.01a§	0.04±0.00a	------	-----	0.01±0.00a	0.01±0.00a
C12:0	0.1±0.03a	0.11±0.04a	0.06±0.01a	0.03±0.01a	0.025±0.01a	0.04±0.01a
C13:0	0.07±0.01a	0.07±0.02a	0.02±0.00a	-----	0.01±0.00a	------
C14:0	6.86±0.62a	7.14±1.21a	2.71±0.32a	2,15±0,01a	3.73±0.09a	3.32±0.11a
C15:0	1.27±0.04a	1.32±0.13a	0.95±0.03a	0,94±0,01a	0.66±0.28a	0.61±0.07a
C16:0	20.26±1.28a	23.18±0.50b	22.53±1.09a	27,90±0,05b	21.06±1.41a	24.74±1.88b
C17:0	1.81±0.07a	2.35±0.36b	1.44±0.01a	1.57±0.03a	1.70±0.18a	1.58±0.08a
C18:0	5.37±0.14a	6.71±0.63b	4.68±0.20a	5,45±0,02b	7.87±0.77a	9.02±0.22b
C20:0	0.93±0.10a	1.74±0.11b	0.39±0.08a	0,36±0,05a	0.29±0.06a	0.58±0.08b
C21:0	2.18±0.10a	1.57±0.40a	0.52±0.11a	0,23±0,13b	0.83±0.22a	0.70±0.17b
C22:0	0.37±0.30a	0.18±0.24a	0.38±0.06a	0,23±0,01a	0.38±0.06a	0.37±0.13a
C24:0	0.40±0.08a	0.52±0.10a	0.15±0.02a	0,11±0,01a	0.66±0.45a	0.49±0.11b
∑SFA	**39.66±2.03**	**44.34±1.35**	**33.82±0.82**	**38.99±0.65**	**37.20±1.54**	**41.46±2.25**
C14:1 ω5	0.18±0.04a	0.20±0.03a	0.14±0.08a	0.33±0.01b	0.07±0.01a	0.08±0.01a
C15:1 ω5	0.22±0.06a	0.22±0.02a	0.50±0.08a	0.76±0.01a	0.24±0.06a	0.15±0.03b
C16:1 ω7	8.46±0.28a	8.91±1.06b	12.41±0.65a	13.98±0.09b	6.84±0.77a	7.85±0.45b
C17:1 ω8	1.10±0.04a	1.10±0.13b	1.41±0.02a	1.36±0.01a	1.11±0.25a	0.86±0.03a
C18:1 ω9	14.29±0.66b	11.74±1.87a	27.25±1.12a	30.77±0.06b	24.30±1.24a	28.94±1.43b
C20:1 ω9	0.77±0.07a	0.52±0.02b	2.91±0.80a	3.34±0.01a	3.97±0.65a	1.78±0.31b
C22:1 ω9	0.31±0.27a	0.08±0.05b	0.87±0.13a	0.55±0.01a	3.71±0.50a	0.14±0.15b
C24:1 ω9	0.39±0.12a	0.48±0.14b	0.42±0.13a	0.01±0.00b	0.98±1.18a	0.27±0.11b
∑MUFA	**25.59±0.68**	**23.25±2.72**	**45.91±1.98**	**51.11±0.09**	**41.23±0.87**	**40.07±1.36**
C18:2 ω6	3.36±0.38a	3.72±0.21a	2.12±1.01a	1.32±0.16b	2.30±0.20a	1.95±0.07a
C18:3 ω6	0.20±0.02a	0.31±0.07b	0.27±0.15a	0.38±0.05a	0.51±0.20a	0,32±0.06a
C18:3 ω3	1.42±0.08a	1.13±0.06a	2.53±0.49a	2.07±0.02a	0.60±0.19a	0.53±0.02a
C20:2 ω6	0.97±0.18a	0.54±0.29b	0.77±0.20a	0.64±0.01a	0.52±0.15a	0.23±0.07b
C20:3 ω6	0.37±0.30a	0.18±0.24a	0.38±0.06a	0.23±0,.00b	0.38±0.06a	0.37±0.13b
C20:3 ω3	1.04±0.08a	1.12±0.03a	0.59±0.06a	0.22±0.02b	0.61±0.04a	0.67±0.15b
C20:4 ω6	1.96±0.35a	1.99±0.15a	2.57±0.06a	1.47±0.01b	0.06±0.05a	1.45±0.29b
C20:5 ω3	8.13±0.09a	7.84±1.05b	5.16±0.08a	1.31±0.66b	5.48±1.91a	3.26±0.42b

C22:2 ω6	0.10±0.01a	0.11±0.04a	0.05±0.02a	0.02±0.01a	0.05±0.01a	0.54±0.12a
C22:5 ω3	-----	-----	----	-----	----	------
C22:6 ω3	16.44±0.52	14.12±1.27	5.48±0,13a	1.47±0.01b	10.27±0.85a	8.75±0.18b
∑PUFA	**33.96±0.97**	**31.07±2.61**	**19.90±1,67**	**9.14±0.23**	**20.77±2.02**	**17.89±0.36**
∑ ω3	27.04	24.22	13.75	5.08	16.97	13.22
∑ ω6	7.14	7,07	6.65	4.82	4.03	4.82
ω3/ ω6	**3.80**	**3.44**	**2.09**	**1.06**	**4.22**	**2.80**

*Values reported are means±S.D.

[§] Average of three lots analysed.

[abc]Values for each sample with different superscript letters in the same fraction are significantly different at $p<0.05$.

In both works, although some differences on the ratios have been observed, MUFA has had the highest values in percentage. Nutrients and seasonal differences in seawater temperature are important parameters for the chemical form and the quality of the muscles of fish species.

In addition to, our present work, it has been found that SFAs, MUFAs and PUFAs have ranged from 44.34% to 26.58%, 45.91% to 25.59% and 33.96% to 9.14% for sea water fish species, respectively. These data are in well agreement with former studies on fatty acids composition in other fish species (Ozogul et al., 2009).

While C22:6 (DHA) increased from October to April, C20:5 (EPA) level gradually declined. Furthermore, the average levels of n3 and n6 were found to be 30.33 and 4.43%, respectively. Significant differences were observed in fatty acid profiles, particularly in C22:6 (DHA), of anchovy during the fishing period (Oksuz and Ozyilmaz, 2010). In our present work, n3 has been measured to be 27.04% in spring and 24.22% in autumn seasons, and n6 has been measured to be 7.14% in spring and 7.07% in autumn in anchovy. In another study, researchers have determined the fatty acid content of anchovy oil produced in Turkey during the commercial catching season. According to this work, the total saturated fatty acids (SFAs) content of anchovy oil has been found to be 32.33% (November), 31.65% (December), and 31.59% (January). EPA and DHA levels of anchovy oil have been determined as average 9.39%, and 15.64% respectively. n-6 PUFAs have been less than n-3 PUFAs (Kaya and Turan, 2008). According to Zlatanos and Laskaridis (2007), the anchovy have showed the maximum variations. In fact, the anchovy has exhibited the two greatest values of n-3 fatty acids among all determined samples in April and June, and four of the five lowest values of these fatty acids have been measured in the other four months. The percent of C20:5n-3 has been found to be 10.1% in average for marine fishes by Ackman (1967). In comparison with other nutrients, the lipids content of fish are especially very rich in long-chain n-3 PUFA e.g., DHA and EPA. The content of 20:5n-3 has ranged from 4.2 to 13.3wt% in all fatty acids and the contents of 22:6n-3 has ranged from 6.6 to 40.8 wt % in the marine fish respectively (Tanakol et al., 1999).

In the work carried out on *T. trachurus,* in the time period between January and August, the level of total lipids has been determined to shows a minimum in February. The fat content has been recorded to be the highest in December and August and lowest in February (Bandarra et al., 2001). According to Borges and Gordo (1991); the spawning period of this species takes place during the first semester of the year showing a peak in February, which might help to explain the low fat content recorded in this month. The SFA fraction has ranged between 30.5% to 26.9% of total fat. (C16:0) has been the most important single fatty acid within this fraction, followed by stearic acid (C18:0). The fatty acid profile reported by Pozo et al., (1992) for the same species (*T. trachurus*) with a fat content of 3.15% was different from that of obtained in *T. trachurus* caught in January. In *T. trachurus*, the palmitic acid, oleic acid and C22:6 were measured to be 17.18%, 14.98% and 22.49% in March, respectively and palmitic acid, SFA, oleic acid, C22.6 and PUFA were measured to be 18.64%, 30.51%, 14.84%, 16.96% and 35.16%, respectively. The palmitic acid, SFA, C20:5, C22:6 and PUFA were found by the same research team to be 27.63%, 17.50%, 11.59%, 16.44% and 38.14%, in October, respectively (Bandarra et al., 2001). In this present work, for the same species, palmitic acid, oleic acid, C22:6 and PUFA have been measured to be 21.06%, 24.30%, 10.27% and 20.77%, respectively, for spring season.

In the study done with *Mullus barbatus* which is from the same family (Mullidae) the fatty acid composition of red mullet has been seen to be influenced from temperature differences. The percents of PUFAs were 20.13% in spring, 17.32% in autumn and 17.69% in winter. Nutrient and seasonal difference in water temperatures are significant factors for quality and chemical composition of fish muscle. The monounsaturated level highly depends on the level of palmitoleic acid (C16:1) and oleic acid (C18:1), since the basic components of this group are firstly oleic acid, and then palmitoleic acid (Polat et al., 2009). In our study, DHA percentage of *Mullus surmuletus* was significantly high in spring (5.48%) before spawning season, but DHA was determined be in low percent in autumn (1.47%) after the spawning time. It is known that DHA is transferred from the muscles to eggs throughout ovulation period. The same results were found by Polat et al., (2009). EPA (C20:5) and DHA (C22:6) were reported to be interchangeable by retrogradation (von Schacky and Weber, 1985). According to Childs et al., (1990), DHA decreases the level of LDL (low density lipoprotein) cholesterol in plasma. Marine fish have higher levels of PUFAs than freshwater fish, especially EPA and DHA (Ozogul and Ozogul, 2007). In present study, n3 was observed that marine species had high percent of the n3 series, ranging from 27.04% for *Engraulis encrasicolus* to 5.08% for *M. surmuletus*. Many researchers have found that the type and amount of fatty acids in fish tissues were affected by the maturity period, seasonal conditions, age and size of the fish species, and geographical features for other fish species (Ackman 1989; Ozyurt et al., 2005).

The fat concent of the sardine was maximal at the end of spring– beginning of summer and minimal at the end of winter (Zlatanos and Laskaridis, 2007). Our study also presents similar results with Zlatanos and Laskaridis (2007) that while the fat content was found to be 9.27% in spring, it was found to be 8.07% in autumn. A low fat content in winter and a high fat content in summer have also been reported for the Japanese sardine *Sardinops melanostictus* (Shirai et al., 2002). Sardine has a superior C22:6n-3 and C20:5n-3 ingredient (Zlatanos and Laskaridis, 2007). PUFAs are required to maintain cell membrane fluidity and membrane protein function; hence, they regulate such processes as gene expression and cell signaling (Das, 2006).

This research has shown that marine fish from the Marmara Sea in Turkey is a desirable item in human diet when its levels of n-3/n-6 ratio, EPA and DHA are considered. It has been found that fish are good food for n-3 fatty acids.

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