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Seasonal variations in proximate and fatty acid compositions of female common sole (*Solea solea*)

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Abstract

The effects of seasonal variation on the proximate and fatty acid compositions of wild female common sole (*Solea solea*) were determined. The levels of lipid displayed pronounced seasonal fluctuations with the highest values in February and August (0.45–0.83% fresh weight) and the lowest values in April and November (0.20–0.13% fresh weight). Although protein levels were similar, dry matter fluctuations were observed for all seasons. In the present study, the percentages of EPA and DHA were between 3.36–4.26% of total lipid and 18.75–20.23% of total lipid, respectively, according to the seasons. The composition of fatty acids in August showed that saturated fatty acids were highest followed by $n-3$ and mono unsaturated fatty acids. The maximum level of $n-6$ was found in February. The results indicated that the $n-3/n-6$ ratios were 3.84, 3.41, 1.89, 1.45 in August, April, November and February, respectively. It was concluded that common sole is a healthy item in the human diet during the fishing period in the eastern Mediterranean coast of Turkey when balanced $n-3/n-6$ ratios and EPA and DHA levels are considered.

Keywords: Common sole; *Solea solea*; Fatty acid; Seasonal variation

1. Introduction

During recent years, fish lipids have been recognised as being beneficial for human health. Many studies have been carried out on the metabolism and function of polyunsaturated fatty acids (PUFAs) in general and on the levels and ratios of $n-3$ and $n-6$ fatty acids in particular. Today it is known that $n-3$ fatty acids, or a balanced $n-3/n-6$ ratio in the diet, are essential for normal growth and development and may play an important role in the prevention and treatment of coronary artery disease, diabetes, hypertension and cancer. They also affect neurodevelopment in infants, fat glycemic control, learning ability and visual function (Carlson & Werkman, 1996; Conner, 1997; De Lorgeril, Salen, Martin, Monjaud, Delaye, & Memelle, 1999; Dyerberg & Bamg, 1979; Goodstine et al., 2003; Kinsella, Lokesh, & Stone, 1990; Kromhout, Bosschieter, & Coulander, 1985; Salem, Simopoulos, Galli, Lagarde, & Knapp, 1996). It is thus important, for human health, to increase the consumption of fish or fish products, which are rich in polyunsaturated fatty acids of the $n-3$ family and poor in polyunsaturated fatty acids of the $n-6$ family (Burr, 1989; Sargent, 1997).

Muscle is the main part of fish used for human consumption (Ackman, 1990) and when fish is suggested as means for improving health, fatty acid composition should be considered. Factors affecting fish composition can be either endogenous or exogenous. The endogenous factors are genetically controlled and are associated with the life cycle of fish. Throughout the year, fish are subjected to considerable environmental changes and fluctuations in availability and compositions of feed that will effect their proximate muscle composition (Olsson, Olsen, Carlehög, & Ofstad, 2002). Many other exogenous factors (temperature and salinity) may also affect the proximate and fatty acid compositions (Bandarra, Batista, Nunes, Empis, & Christie, 1997; Leger, Bergot, Lukuet, Flanzy, & Meurot, 1977; Wodtke, 1981). Furthermore, proteins and lipids are mobilised from muscle and transferred to the gonads in the reproductive period (Sharer, 1994).

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Common sole (*Solea solea*) is one of the commercially important and highly consumed fish species in the eastern Mediterranean. In view of these facts, the aim of this study was to determine seasonal variations of the fatty acid composition and $n-3/n-6$ ratios of the muscle of common sole which has not been studied in the area.

2. Material and methods

This study was carried out in 2001 and samples were obtained quarterly (February, April, August and November) from the local fishers in Iskenderun Bay (Turkey). Because of insufficient number of males obtained, only mature female individuals were used for the analysis. Ten individuals were sampled in each season. The averages for total length and weight of 40 wild common sole were 26.6 ± 0.28 cm and 244 ± 9.33 g, respectively. The status of sexual maturation and reproductive period of fish were determined macroscopically. Boneless fish fillets were used for the analysis.

Fatty acid analysis of fish fillets was carried out using the IUPAC II D10 method. The measurements were made on a Termoquest Trace gas chromatograph equipped with SP-2330 fused silica capillary column, 30×0.25 mm ID 0.20 μm film thickness. The instrument conditions were: initial temperature 120 °C; heating rate 8 °C/min; final temperature 225 °C; injector temperature 240 °C; carrier gas, helium; split ratio 1/150; column flow 75 ml/min; make-up 30 ml/min (He) range 1; sample injection 0.5 μl. The fatty acid methyl mixture No. 189-19 was used for standards (Sigma Chemical Company).

Statistical evaluations were carried out with SPSS (1999) Windows version 10.0. A one-way ANOVA and a Duncan's multiple range tests were used to compare means at 0.05 probability level.

3. Results and discussion

Substantial differences between the seasons were observed in the lipid levels of the common sole. The highest level of lipid was found in August, during higher temperature, while the lowest was in November. Although dry matter fluctuations were observed for all seasons, protein levels were similar except for November (Table 1). Researching the effect of climate on lipid content variation, Krzynowek (1985) reported that the fat content of some fish species might vary by approximately 10% according to the season. The percentage of body fat is known to depend on the life cycle stage and energy intake of the animal (Jobling, 1994; Weatherley & Gill, 1987) and higher temperature periods are characterised by faster growth rates and large intakes (Garcia Garcia, Rueda, Hernandez, Aguado, Egea, & Faraco, 2001).

Macroscopic observations carried out on ovary indicated that the reproductive season of the species is between April and June. A previous report on the reproductive period of the species for the same area confirmed the result of the present study (Turkmen, 2003). Low levels of lipid were observed in the reproductive season of the species and at the end of autumn. Sexual maturation has been found to reduce lipid body stores in salmon because this species stops feeding during maturation and lipid stores are directed to gonad lipids or used for energy (Bell, McEvoy, Webster, McGhee, Millar, & Sargent, 1998). Other studies have also shown that, although sea bream does not stop feeding, reduced feeding level and sexual maturation contribute to reduced lipid levels during winter (Grikorakis, Alexis, Taylor, & Hole, 2002). As many fish species tend to reduce their food intake during sexual maturation, essential fatty acids and other nutrients needed for ovarian growth are taken from the reserves in their bodies. Female rainbow trout (*Onchorhynchus mykis*) mobilise mainly the carcass and visceral lipid reserves (Nassour & Leger, 1989). Fresh water catfish (*Clarias batrachus* L.) use abdominal fat as the major energy source for sexual maturation (Lal & Singh, 1987), while Atlantic salmon (*Salmo salar* L.) use both muscle lipid and protein (Aksnes, Gjerde, & Roald, 1986). Atlantic cod (*Gadhus morhua* L.) use lipid reserves accumulated in the liver during the autumn and early winter (Tocher & Harvie, 1988).

In individuals caught off the Turkish coast in the eastern Mediterranean, the maximum level of lipid determined in August may indicate increasing feeding and growth rate of fish. The increase of lipid level in summer may also be explained by an enhanced feeding activity due to higher sea water temperature and increased day

Table 1
Proximate composition of common sole in different seasons (% fresh weight)

	February	April	August	November
Protein	19.4 ± 0.09 a	19.5 ± 0.15 a	19.2 ± 0.11 a	16.0 ± 0.09 b*
Dry matter	22.8 ± 0.08 d	21.6 ± 0.03 c	17.5 ± 0.06 a	20.2 ± 0.08 b
Ash	1.31 ± 0.04 c	1.14 ± 0.01 b	0.81 ± 0.07 a	1.10 ± 0.01 b
Lipid	0.45 ± 0.02 a	0.20 ± 0.01 b	0.83 ± 0.01 c	0.13 ± 0.03 d

* Averages followed by the same letter show no statistical differences ($p < 0.05$).

length which have a positive influence on appetite (Forsberg, 1995; Mallekh, Lagardere, Begout Ahras, & Lafaye, 1998; Olsson et al., 2002; Smith, Metcalfe, Huntigford, & Kadri, 1993). An increase in the lipid level resulted in an increase also in the fatty acid levels, except for $n-6$. However, most of the fatty acids determined in August were saturated fatty acids, followed by $n-3$ and mono unsaturated fatty acids. The maximum level of $n-6$ was found in February.

From these results, it could be speculated that common sole uses lipid as an energy source. In contrast to $n-3$ and other fatty acids, the $n-6$ series appears to be utilised more (Table 2).

Trawl fishing of this species is carried out in autumn and winter. In the summer season trawling is banned by the Turkish ministry of Agriculture. In the fishing season, lipid levels were between 0.83 and 0.45 (Table 1). However, the lipid and protein levels were decreased in November when the sea water temperature decreased. From November, these values rose again until April, which is the beginning of the reproductive period.

The fatty acid profiles of flesh lipids of common sole are listed in Table 2. In the present study, the percentages (in total lipid) of EPA and DHA which have a vital role in human nutrition were between 3.36–4.26 and 18.8–20.2, respectively, according to the seasons. Soriguer et al. (1997) found that DHA level was 14.8 (% of total lipid) in sole sampled in the southern coast of Spain. In another study, Riley (1999) determined DHA and EPA percentages to be 14.4 and 7.3, respectively, for common sole. The values found for different seasons in the present study were similar to or higher than the values determined in previous studies for the same species. The results on the seasonal variations of EPA and DHA are in good agreement with previous reports carried out on seasonal variations of fatty acid compositions of different species as well (Grün, Shi, Fernando, Clarke, Ellersieck, & Beffa, 1999; Shirai, Terayama, & Tekada, 2002; Shirai, Suzuki, Tokairin, Ehara, & Wada, 2002).

Luzia, Sampaio, Castellucci, and Torres (2003) determined the EPA + DHA values of sardine, croaker, tilapia and curimbata for summer and winter and they reported that the highest amount of EPA + DHA was 13.5% for Tilapia. The lowest percentage of EPA + DHA in sole analysed was 22.1, which is significantly higher than the four species mentioned above. The percentages of EPA and DHA were investigated for sea bass by Alasalvar, Taylor, Zubcov, Shahidi, and Alexis (2002). While the amount of DHA was similar, EPA level was higher than that of the sole found in the present study.

The $n-3/n-6$ ratio is a good index for comparing relative nutritional value of fish oils (Piggott & Tucker, 1990). However, there is no recommended intake in terms of $n-3/n-6$ ratios but evidence in wild animals and estimated nutrient intake during human evolution suggest a diet ratio of 1:1 (Simopoulos, 1989).

As a consequence, when human health is taken into account, the sole from the eastern Mediterranean appears to be quite nutritious in terms of fatty acid level and ratio. The present data show that the $n-3/n-6$ ratio was 3.84 in August, 3.41 in April, 1.89 in November and that the lowest value 1.45 was in February. A high level of $n-6$ lowered the $n-3/n-6$ ratio in February.

Table 2
Seasonal fatty acid composition of common sole (% of total lipid)

Fatty acids	February	April	August	November
C14:0	1.45 ± 0.09 b	1.45 ± 0.05 b	1.47 ± 0.02 b	2.15 ± 1.10 c*
C15:0	1.00 ± 0.02 c	0.98 ± 0.00 c	0.71 ± 0.01 b	0.19 ± 0.00 a
C16:0	17.9 ± 0.07 b	15.3 ± 0.06 a	19.0 ± 0.20 c	18.5 ± 0.22 c
C17:0	1.59 ± 0.01 b	1.41 ± 0.01 ab	1.55 ± 0.01 b	1.35 ± 0.09 a
C18:0	6.78 ± 0.00 b	5.82 ± 0.01 a	6.91 ± 0.01 b	6.13 ± 0.02 a
C14:1	0.16 ± 0.04 b	0.02 ± 0.00 a	0.17 ± 0.00 b	0.26 ± 0.00 c
C16:1	2.65 ± 0.02 a	3.39 ± 0.02 b	4.16 ± 0.03 c	4.23 ± 0.11 c
C18:1$n-9c$	7.57 ± 0.06 a	8.49 ± 0.00 b	10.1 ± 0.09 c	9.55 ± 0.27 c
C20:1$n-9c$	0.34 ± 0.09 a	0.27 ± 0.00 a	1.10 ± 0.00 b	0.21 ± 0.00 a
C24:1$n-9$	3.15 ± 0.03 d	1.93 ± 0.01 c	0.16 ± 0.00 a	0.43 ± 0.02 b
C20:2$n-11.14c$	0.30 ± 0.00 c	0.12 ± 0.00 a	0.43 ± 0.00 d	0.27 ± 0.02 b
C18:2$n-6$	0.89 ± 0.02 b	0.42 ± 0.00 a	0.48 ± 0.00 a	2.03 ± 0.05 c
C18:2$n-6c$	0.70 ± 0.00 a	0.91 ± 0.03 b	1.13 ± 0.01 c	1.16 ± 0.03 c
C20:4$n-6$	12.3 ± 0.07 d	5.54 ± 0.02 b	4.72 ± 0.02 a	8.36 ± 0.26 c
C18:3$n-3\alpha$	0.12 ± 0.04 a	0.12 ± 0.00 b	0.19 ± 0.01 bc	0.24 ± 0.00 c
C20:5$n-3$	3.36 ± 0.03 a	4.26 ± 0.03 c	3.89 ± 0.02 b	3.43 ± 0.10 a
C22:6$n-3$	16.8 ± 0.18 a	19.0 ± 0.07 bc	20.2 ± 0.31 c	18.2 ± 0.51 b
$\sum n-3$	20.2	23.4	24.3	21.9
$\sum n-6$	13.93	6.87	6.33	11.6
$n-3/n-6$	1.45	3.41	3.84	1.89
$\sum$PUFA	4.0	2.0	1.0	3.0

* Averages followed by the same letter show no statistical differences ($p < 0.05$).

An increase in the human dietary $n-3/n-6$ fatty acid ratio is essential in the diet to help coronary heart disease by reducing plasma lipids and to reduce cancer risk (Kinsella et al., 1990). It is thus important for human health to increase the consumption of $n-3$ fatty acids (Coetzee & Hoffman, 2002; Simopoulos, 1991). This study has shown that the common sole is a suitable item in the human diet during the fishing period in the eastern Mediterranean coast of Turkey when the levels of EPA, DHA and $n-3/n-6$ ratio are considered.

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