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The effects of season and sex on fat, fatty acids and protein contents of *Sepia officinalis* in the northeastern Mediterranean Sea

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Abstract
The effects of season and sex on the fatty acids (FAs) and proximate compositions of the mantle of the mature common cuttlefish were evaluated. The results of the proximate composition showed that the lowest lipid content was obtained from females in winter (0.74%), whereas the highest level of lipid was found in males in autumn (0.94%; $p < 0.05$). The protein levels of the mantle of the mature male of common cuttlefish were significantly higher ($p < 0.05$) than those found in female specimens. The FA compositions of each sex for all seasons ranged from 29.4% to 32.5% saturated FAs, 8.7–11.1% monounsaturated FAs and 48.2–54.6% polyunsaturated fatty acids (PUFAs). The proportions of *n*-3 PUFAs (44.0–50.6%) were higher than *n*-6 PUFAs (3.4–4.3%) regardless of sex and seasons. The levels of eicosapentaenoic acid in the mature common cuttlefish mantle in spring, autumn and winter were 15.9–17.8%, 16.3–17.2% and 15.7–16.8% while those of docosahexaenoic acid were 32.5–33.0%, 27.5–29.0% and 28.7–31.1%, respectively.

Keywords: *mature common cuttlefish, season, sex, fatty acids, proximate composition*

Abbreviations: *AI, atherogenicity index; TI, thrombogenicity index; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; FA, fatty acid; FAME, fatty acid methyl ester; FID, flame ionization detector; GC, gas chromatography; ML, mantle length; TL, total length*

Practical application

Marine foods are an important part of the Mediterranean diet. The beneficial effect of seafood consumption on human health has been related to the high content of *n*-3 fatty acids (FAs), especially eicosapentaenoic acid (EPA; C20:5 *n*-3) and docosahexaenoic acid (DHA; C22:6 *n*-3). The *n*-3:*n*-6, eicosapentaenoic (PUFA)/saturated fatty acid (SFA) and EPA + DHA ratios are considered to be useful criteria for comparing relative nutritional and oxidation values of marine oils. In this study, the influence of seasonality and sex on the proximate and the FA composition of the cuttlefish were investigated in order to find the best source of *n*-3 FAs during the year.

Introduction

Cephalopods including cuttlefish, squid and octopus are an important marine resource since they are rich in taste and nutrients (Sikorski and Kolodziejska 1986; Ozogul et al. 2008). Annual catch of cephalopods in 2008 reached to 4,313,510 tons throughout the world (FAO 2008). *Sepia officinalis*, known as common cuttlefish or European cuttlefish, belongs to the *Sepiidae* family. There exist over 120 cuttlefish species throughout the world (Reid et al. 2005). Of these, *S. officinalis* is one of the best known, easily cultivated and highly preferred species by consumers (Forsythe et al. 1994). This species is distributed from the Baltic and Northern Seas in the east Atlantic to Africa, and the Mediterranean (Roper et al. 1984). According to Anonymous (2010) report, 1502 and 1258 tons of cuttlefish were caught in 2008 and 2009, respectively, in Turkey. Due to their nutritional and market values, cephalopod aquaculture has also shown an increase during the past few years (Almansa et al. 2006).

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Consumption of seafood is found to protect against lifestyle diseases that pose health challenges in most countries. Abundant evidence shows that seafood, especially oily fish, reduces the risk of cardiovascular disease and cardiovascular events (de Leiris et al. 2009; Marik and Varon 2009; Saremi and Arora 2009) owing to the high concentrations of *n*-3 PUFAs present in many species. FAs are chemicals that contain carbon, oxygen and hydrogen in repeating groups of $-(CH_2)n$ – that contain both a methyl (CH_3) group and a carboxyl (—COOH) group. Highly unsaturated FAs with one of the double bonds located three carbon atoms from the methyl end are denoted *n*-3 FAs. Those *n*-3 PUFAs are particularly important in human nutrition, including 18:3 alpha-linolenic acid, 20:5 EPA, 22:5 docosapentaenoic acid and 22:6 DHA. Globally, the most commonly consumed sources of *n*-3 PUFAs are fish, shellfish and cephalopods, which in turn obtain them from algae that can synthesize these FAs. Concentrations of *n*-3 PUFAs vary greatly among seafood species (Mahaffey 2004; Chung et al. 2008; Weaver et al. 2008; Ozogul et al. 2009). Thus, dietary intake of EPA and DHA from seafood is strongly dependent on the species consumed. General recommendations for daily dietary intakes of DHA/EPA are 0.5 g for infants and 1 g/day for adults (Kris-Etherton et al. 2002). Although cephalopods contain low levels of fat, it is rich in *n*-3 FAs (Passi et al. 2002; Ozyurt et al. 2006; Zlatanos et al. 2006). The FA composition of seafood reflects the FA composition of their natural foods (Henderson and Tocher 1987; Van Vliet and Katan 1990; Grigorakis et al. 2002). It has been well known that diet, location and season are the major factors affecting the composition of fish muscle.

Some studies have been conducted on the FA, proximate composition, thermal property and protein digestibility corrected amino acid score of common cuttlefish (Shchenikova et al. 1987; Soriguer et al. 1997; Sinanoglu and Miniadis-Meimaroglu 1998; Horrocks and Yeo 1999; Ozyurt et al. 2006; Reale et al. 2006; Thanonkaew et al. 2006; Zlatanos et al. 2006). Chemical compositions of cephalopods have also been reported to change due to seasonal changes (Ozyurt et al. 2006; Ozogul et al. 2008). Therefore, the aim of this study was to investigate the effects of season and also sex on the FAs and protein compositions of the mantle tissue of the common cuttlefish (*S. officinalis*) in Mersin Bay, Northeastern Mediterranean Sea.

Materials and methods

Materials

The common cuttlefish is generally caught in the Mediterranean and Aegean Seas in Turkey. In this study, the species used was caught with net in all seasons (except summer) in Mersin Bay, Northeastern Mediterranean in 2009. In the fishing procedure, dip net that had a mesh size of 32 mm was used. In every season, 20 male and 20 female individuals of this species were taken and kept in polystyrene boxes filled with ice and transferred to the laboratory.

Sample preparation

The morphometric measurements [mantle length (ML), total length (TL)] and weight of all samples were recorded (Table I). The morphometric measurements of samples were taken using a caliper. Mantle, which is the main edible portion of cuttlefish, was homogenized and chemical analyses were carried out in fresh samples. The analyses were carried out in triplicate.

Proximate analysis

The following chemical constituents were determined on samples of all muscles according to the official methods of analysis of the AOAC (2003) moisture content by oven drying a ca. 2-g test sample at 102°C to a constant weight (950.46B, see p. 39.1.02); total mineral substance (TMS) content by igniting a *ca.* 3–5-g test sample in a muffle furnace at 550°C until light grey ash results (920.153, see p. 39.1.09); crude protein content by the classical macro-Kjeldahl method (981.10, see p. 39.1.19); and lipid (crude) content by Bligh and Dyer (1959) using chloroform/methanol extraction.

Fatty acid methyl ester (FAME) analyses

FA profiles of fat extracted from the cuttlefish samples were determined by gas chromatography (GC). Methyl esters were prepared by transmethylation using 2 M KOH in methanol and *n*-heptane according to the method described by Ichihara et al. (1996) with minor

Table I. Morphological measurements of cuttlefish in the Northeastern Mediterranean Sea.

Season	NS	ML (mm) $\bar{X} \pm S_{\bar{X}}$	Min–max	TL (mm) $\bar{X} \pm S_{\bar{X}}$	Min–max	Weight (g) $\bar{X} \pm S_{\bar{X}}$	Min–max	Sex
Autumn	20	113.75 ± 3.85^{a}	**110.0**–117.5	398.75 ± 19.24^{a}	380.0–417.5	172.31 ± 22.64^{a}	150.24–194.38	♀
	20	122.70 ± 7.30^{ab}	115.0–132.0	426.38 ± 15.90^{ab}	415.0–447.5	199.21 ± 30.07^{a}	160.74–233.62	♂
Winter	20	146.00 ± 7.17^{bc}	135.0–**155.0**	468.80 ± 35.22^{bc}	425.0–518.0	337.87 ± 41.80^{b}	270.14–390.51	♀
	20	163.50 ± 14.63^{c}	144.0–**183.0**	521.00 ± 47.65^{c}	465.0–581.0	345.14 ± 81.00^{b}	262.90–477.13	♂
Spring	20	117.95 ± 5.87^{ab}	112.0–130.0	398.75 ± 19.24^{a}	380.0–417.5	201.56 ± 20.88^{a}	180.21–240.11	♀
	20	124.10 ± 8.70^{ab}	**110.0**–139.0	420.38 ± 23.58^{a}	380.0–447.5	194.09 ± 21.61^{a}	167.59–232.4	♂

Notes: NS, number of specimens; ML, mantle length; TL, total length. Within the column, values with different letters are significantly different ($p < 0.05$). $\bar{X} \pm S_{\bar{X}}$: mean ± standard error. Bold values show the smallest and highest average value.

Table II. Proximate compositions of male and female cuttlefish in different seasons (%).

Season	Protein $\bar{X} \pm S_X$	Lipid $\bar{X} \pm S_X$	Water $\bar{X} \pm S_X$	TMS $\bar{X} \pm S_X$	Sex
Autumn	17.33 ± 0.10[bc]	0.84 ± 0.06[bc]	80.65 ± 0.08[d]	**1.07 ± 0.10**[a]	♀
	16.96 ± 0.15[a]	**0.94 ± 0.02**[c]	**80.75 ± 0.09**[d]	1.08 ± 0.04[a]	♂
Winter	22.01 ± 0.12[d]	**0.74 ± 0.00**[a]	75.44 ± 0.34[ab]	1.64 ± 0.05[b]	♀
	21.64 ± 0.28[c]	0.82 ± 0.00[b]	75.52 ± 0.19[bc]	1.59 ± 0.02[b]	♂
Spring	**22.18 ± 0.00**[d]	0.89 ± 0.04[c]	**75.00 ± 0.02**[a]	**1.75 ± 0.03**[c]	♀
	21.47 ± 0.18[c]	0.91 ± 0.02[c]	75.78 ± 0.07[c]	1.73 ± 0.01[c]	♂

Notes: Within the rows, values with different letters are significantly different ($p < 0.05$). $\bar{X} \pm S_X$: Mean ± SD. Bold values show the smallest and highest average.

modification. Extracted lipids (10 mg) were dissolved in 2 ml of *n*-heptane followed by 4 ml of 2 M methanolic KOH. The tube was then vortexed for 2 min at room temperature. After centrifugation at 4000 rpm for 10 min, the heptane layer was taken for GC analyses.

Gas chromatographic condition

The FA composition was analysed by the GC Clarus 500 with autosampler (Perkin–Elmer, Shelton, CT, USA) equipped with a flame ionization detector (FID) and a fused silica capillary SGE column (30 m 0.32 mm, ID 0.25 mm, BP20 0.25 UM; SGE Analitic Science Pty Ltd, Victoria, Australia). The oven temperature was 140°C, held for 5 min, raised to 200°C at a rate of 4°C/min and to 220°C at a rate of 1°C/min, while the injector and the detector temperature were set at 220°C and 280°C, respectively. The sample size was 1 μl and the carrier gas helium was controlled at 16 ps. The split used was 1:100. FAs were identified by comparing the retention times of fatty acid methyl esters (FAMEs) with a standard 37-component FAME mixture (catalogue no. 18919; Supelco, Germany). Triplicate GC analyses were carried out and the results were expressed in GC area % as the mean value ± standard deviation (SD).

Atherogenicity index (AI) and thrombogenicity index (TI)

The AI and TI linked to the FA composition were calculated according to Ulbricht and Southgate (1991).

$$\mathrm{IA} = [(a \times 12:0) + (b \times 14:0) + (c \times 16:0)] \times [d \times (\mathrm{PUFAs}\, n-6 + n-3) + e \times (\mathrm{MUFAs}) + f \times (\mathrm{MUFAs} - 18:1)]$$

$$\mathrm{IT} = [g \times (14:0 + 16:0 + (18:0)] \times [(h \times \mathrm{MUFAs}) + i \times (\mathrm{MUFAs} - 18:1) + (m \times n - 6) + (n \times n - 3) + (n - 3/n - 6)]$$

$$a, c, d, e,\ f = 1,\ b = 4,\ g = 1,\ h, i, m = 0.5$$

and $n = 3$.

Statistical analysis

Prior to the analyses, all data were checked for outliers (*Z* values were checked) and homogeneity of variance (the Duncan test was used) was also tested. Statistical analysis of data was carried out with the SPSS statistical programme. Analysis of variance was used to evaluate the effects of sex and season on the FA and proximate composition.

Results and discussion

Sexual maturation

In this study, the annual ranges of MLs of female and male cuttlefish were 110–155 and 110–183 mm, respectively (Table I). In a study carried out by Erdal et al. (2007) in Antalya Bay, males with the ML over 87 mm and females with the ML over 100 mm were accepted as mature. Thus, according to the results of this study, male and female common cuttlefish used in our study were evaluated as mature.

Proximate analyses

The results of the proximate composition showed that season and sex affected the proximate composition of cuttlefish. The lowest lipid content was obtained from females in winter (0.74%) whereas the highest level of lipid was found in males in autumn (0.94%; $p < 0.05$; Table II). Generally, lipid contents of males for all seasons were observed to be higher than those of females. However, the lipid content of this species was found to be very low and the species were all considered as lean (fat content <3%). Similar results were found in cephalopod molluscs (cuttlefish, octopus and squid; Ozyurt et al. 2006; Reale et al. 2006; Zlatanos et al. 2006; Ozogul et al. 2008).

The protein content of cuttlefish was found to be quite high. However, the lowest protein content was obtained in autumn (16.96–17.33%). The protein contents of cuttlefish did not change in both spring (21.47–22.18%) and winter (21.64–22.01%) seasons (Table II). Ozogul et al. (2008) reported that protein content of cuttlefish was 16.91% in spring, 18.77% in autumn and 16.91% in winter. In this study, the level of protein contents of female cuttlefish was significantly higher than those of males ($p < 0.05$) for

Table III. FA compositions of male and female cuttlefish in different seasons (%).

FA	Autumn		Winter		Spring	
	♀ $\bar{X} \pm S_X$	♂ $\bar{X} \pm S_X$	♀ $\bar{X} \pm S_X$	♂ $\bar{X} \pm S_X$	♀ $\bar{X} \pm S_X$	♂ $\bar{X} \pm S_X$
C12:0	0.02 ± 0.00[a]	0.02 ± 0.00[a]	0.08 ± 0.00[c]	0.05 ± 0.00[b]	0.02 ± 0.00[a]	**ND**
C14:0	2.38 ± 0.22[bc]	**2.43 ± 0.08**[c]	1.70 ± 0.10[a]	2.12 ± 0.02[b]	**1.56 ± 0.07**[a]	1.58 ± 0.07[a]
C15:0	0.89 ± 0.02[b]	0.95 ± 0.01[c]	0.71 ± 0.04[a]	0.73 ± 0.03[a]	0.72 ± 0.01[a]	0.72 ± 0.02[a]
C16:0	18.25 ± 0.38[c]	18.80 ± 0.19[cd]	18.16 ± 0.17[c]	**19.24 ± 0.12**[d]	**16.38 ± 0.26**[a]	17.57 ± 0.03[b]
C17:0	**1.63 ± 0.03**[a]	1.54 ± 0.00[a]	1.46 ± 0.10[a]	**1.41 ± 0.08**[a]	1.58 ± 0.09[a]	1.45 ± 0.07[a]
C18:0	8.56 ± 0.15[c]	**7.45 ± 0.07**[a]	**9.27 ± 0.23**[e]	8.67 ± 0.12[c]	8.83 ± 0.04[d]	8.20 ± 0.03[b]
C20:0	0.14 ± 0.02[d]	0.11 ± 0.02[bc]	0.13 ± 0.00[d]	0.12 ± 0.00[c]	0.09 ± 0.01[b]	0.07 ± 0.01[a]
C22:0	0.36 ± 0.03[c]	0.34 ± 0.01[c]	0.27 ± 0.00[b]	0.17 ± 0.01[a]	0.20 ± 0.02[a]	0.19 ± 0.01[a]
ΣSFA	32.23	31.65	31.78	**32.51**	**29.38**	29.78
C14:1	0.11 ± 0.01[b]	0.10 ± 0.01[b]	0.07 ± 0.02[a]	0.06 ± 0.01[a]	0.07 ± 0.01[a]	0.06 ± 0.01[a]
C15:1	0.19 ± 0.01[c]	0.18 ± 0.01[c]	0.14 ± 0.01[b]	0.12 ± 0.01[a]	0.13 ± 0.00[a]	0.12 ± 0.01[a]
C16:1	**1.31 ± 0.14**[c]	1.16 ± 0.05[bc]	1.08 ± 0.05[b]	**0.90 ± 0.01**[a]	0.93 ± 0.11[ab]	1.04 ± 0.12[b]
C17:1	0.21 ± 0.02[c]	0.22 ± 0.01[c]	0.15 ± 0.01[b]	0.13 ± 0.01[a]	0.13 ± 0.01[a]	0.15 ± 0.01[b]
C18:1 *n*9	**5.15 ± 0.61**[e]	4.91 ± 0.21[de]	4.66 ± 0.15[d]	3.68 ± 0.11[b]	**3.31 ± 0.06**[a]	3.80 ± 0.07[c]
C18:1 *n*7	2.24 ± 0.02[d]	2.11 ± 0.01[c]	**2.57 ± 0.22**[e]	1.91 ± 0.01[a]	**1.89 ± 0.02**[a]	2.03 ± 0.01[b]
C20:1	4.11 ± 0.17[c]	**3.49 ± 0.01**[a]	**4.82 ± 0.19**[d]	3.78 ± 0.02[b]	4.70 ± 0.13[d]	4.28 ± 0.07[c]
C22:1 *n*9	0.03 ± 0.00[a]	0.03 ± 0.00[a]	0.03 ± 0.00[a]	0.03 ± 0.00[a]	0.03 ± 0.00[a]	**ND**
ΣMUFA	13.35	12.19	**13.53**	**10.61**	11.19	11.48
C18:2 *n*6	0.58 ± 0.03[b]	**0.49 ± 0.05**[a]	0.60 ± 0.03[b]	0.50 ± 0.04[a]	0.54 ± 0.02[a]	**0.77 ± 0.04**[c]
C18:3 *n*6	0.03 ± 0.01[a]	0.03 ± 0.00[a]	0.17 ± 0.02[b]	0.16 ± 0.02[b]	0.06 ± 0.07[a]	0.04 ± 0.01[a]
C18:3 *n*3	0.25 ± 0.00[b]	0.22 ± 0.00[a]	0.34 ± 0.03[c]	0.25 ± 0.02[b]	0.35 ± 0.01[c]	0.51 ± 0.01[d]
C20:2 cis	0.42 ± 0.03[c]	0.37 ± 0.02[b]	0.34 ± 0.02[ab]	0.31 ± 0.02[a]	0.40 ± 0.01[c]	0.36 ± 0.01[b]
C20:3 *n*6	**ND**	**ND**	0.23 ± 0.00[a]	0.28 ± 0.01[b]	**ND**	**ND**
C20:4 *n*6	3.09 ± 0.15[b]	2.87 ± 0.19[a]	2.94 ± 0.10[ab]	3.31 ± 0.10[c]	**2.78 ± 0.05**[a]	**3.38 ± 0.04**[c]
C20:5 *n*3	16.29 ± 0.42[ab]	17.22 ± 0.23[c]	**15.73 ± 0.12**[a]	16.80 ± 0.04[b]	**17.75 ± 0.17**[d]	15.85 ± 0.17[a]
C22:2 cis	0.11 ± 0.01[b]	0.11 ± 0.00[b]	0.14 ± 0.01[c]	0.09 ± 0.00[a]	0.15 ± 0.01[c]	0.09 ± 0.01[a]
C22:6 *n*3	**27.46 ± 0.77**[a]	29.23 ± 0.53[c]	28.70 ± 0.11[b]	31.14 ± 0.10[d]	32.54 ± 0.04[e]	**33.02 ± 0.06**[f]
ΣPUFA	**48.23**	50.55	49.20	52.84	**54.57**	54.02
PUFA/SFA	**1.50**	1.60	1.55	1.63	**1.86**	1.81
Σ*n*6	3.70	3.40	3.95	**4.25**	**3.38**	4.19
Σ*n*3	**44.00**	46.68	44.77	48.19	**50.63**	49.38
n6/n3	0.08	**0.07**	**0.09**	**0.09**	0.07	**0.09**
AI	**0.46**	**0.46**	0.40	0.44	**0.35**	0.37
TI	**0.19**	0.18	**0.19**	0.18	**0.15**	0.16
Unidentified	6.19	5.61	5.50	4.04	4.86	4.72

Notes: Within the rows, values with different letters are significantly different ($p < 0.05$). ND: not detected; $\bar{X} \pm S_X$: Mean ± SD. Bold values show the smallest and highest average value.

all seasons. The results have indicated that both males and females of this species are an excellent protein source and low in fat content as reported in previous studies for cuttlefish (Reale et al. 2006; Zlatanos et al. 2006; Ozogul et al. 2008).

The lowest TMS content was obtained in autumn (1.07–1.08%), whereas the highest level of TMS was obtained in spring (1.73–1.75%) in both females and males. TMS contents of cuttlefish were also found to be significantly different ($p < 0.05$) among the seasons, indicating that TMS levels were affected by season but no differences were observed between the levels of TMS of males and females. Reale et al. (2006) and Zlatanos et al. (2006) reported 1.51% and 2.1% TMS contents for cuttlefish, respectively. In addition, Ozogul et al. (2008) reported 1.12% in spring, 1.69% in autumn and 2.11% in winter.

The highest water content ($p < 0.05$) was obtained in autumn (~81%) whereas the water content of cuttlefish in winter and spring was found to be approximately 76%. The water content of female cuttlefish was generally low compared to that of male cuttlefish although no significant differences were observed ($p < 0.05$). It was also reported that the water content of cuttlefish ranged from ~80% to 81% in spring and winter to ~78% in autumn (Ozogul et al. 2008).

Fatty acids composition

The results of the FA analysis showed that the cuttlefish were very rich *n*-3 PUFAs (especially EPA and DHA). The FA compositions of each sex for all seasons ranged from 29.38% to 32.51% saturated (SFA), 10.61–13.53% monounsaturated (MUFAs) and 48.23–54.57% polyunsaturated acids (PUFAs). The major FAs found in cuttlefish were myristic acid (C14:0, 1.56–2.43%), palmitic acid (C16:0, 16.38–19.24%), heptadecanoic acid (C17:0, 1.41–1.63%), stearic acid (C18:0, 7.45–9.27%), palmitoleic acid (C16:1 *n*-7, 0.90–1.31%), oleic acid (C18:1 *n*-9, 3.31–5.15%), *cis*-vaccenic acid (C18:1 *n*-7, 1.89–2.57%), *cis*-11-eicosenoic acid (C20:1 *n*-9, 3.49–4.82%), linoleic acid (C18:2 *n*-6, 0.49–0.77%), arachidonic acid (C20:4 *n*-6 2.78–3.38%),

cis-5,8,11,14,17-EPA (C20:5 *n*-3, 15.73–17.75%) and *cis*-4,7,10,13,16,19-DHA (C22:6 *n*-3, 27.46–33.02%; Table III). These results were in agreement with those reported for cuttlefish (Ozyurt et al. 2006; Reale et al. 2006; Zlatanos et al. 2006; Ozogul et al. 2008).

Palmitic acid (C16:0) was the primary SFA, contributing 55.75–57.10% and 58.99–59.39% of the total SFA content of lipids for females and males of cuttlefish, respectively. Stearic acid (C18:0) was the second most abundant SFA and accounted for 26.55–30.05% and 23.44–27.53% of total SFA for females and males of cuttlefish, respectively. Similar values were reported for same species (Ozyurt et al. 2006; Ozogul et al. 2008).

Oleic acid (C18:1 *n*-9) and *cis*-11-eicosenoic acid (C20:1 *n*9) were the most abundant MUFA. Oleic acid accounted for 29.57–38.57% and 33.10–40.27% of total MUFA whereas *cis*-11-eicosenoic acid contributed 30.78–42% and 28.63–37.28% for female and male cuttlefish, respectively. The highest level of MUFA (13.53%) was obtained from female cuttlefish in winter whereas the lowest MUFA (10.61%) was obtained from male cuttlefish in winter. However, Ozyurt et al. (2006) and Ozogul et al. (2008) reported lower MUFA levels regardless of sex for all seasons, ranging from 7.81% in spring to 9.84% in autumn, and from 6.89% in autumn to 8.26% in winter.

The major FAs identified as PUFA were EPA (C20:5 *n*-3), and DHA (C22:6 *n*-3), accounting for 31.97–33.61%, 29.34–34.06% and 56.93–59.62%, 57.82–61.12% of total PUFA for females and males of cuttlefish, respectively. The proportion of these FAs changed significantly throughout seasons. DHA was the most abundant *n*-3 PUFA in the cuttlefish observed. In addition, the levels of DHA in male cuttlefish were significantly ($p < 0.05$) higher than those of female cuttlefish in all seasons. EPA is the most important essential FA of the *n*-3 series in the human diet because it is the precursor to the three-series eicosanoids (Chen et al. 1995). The levels of EPA were observed to be high in males of cuttlefish in autumn and winter. However, its level was found to be high in females of cuttlefish in spring. DHA and EPA were reported to be interchangeable by retrogradation (Von Schacky and Weber 1985).

It was observed that mantle meat of cuttlefish had a rich content of *n*-3 FA (44.00–50.63%). The proportions of *n*-3 PUFAs (44.00–50.63%) were higher than *n*-6 PUFAs (3.38–4.25%) regardless of sex and seasons (Table III). The UK Department of Health recommends a maximum dietary ratio of *n*-6/*n*-3 of 4.0 (HMSO 1994). Values higher than the maximum value are harmful to health and may promote cardiovascular diseases (Moreira et al. 2001). In this study, the ratio *n*-6/*n*-3 was found to range from 0.07 to 0.09, which were lower than those in the previous study (Ozogul et al. 2008). A minimum value of PUFA/SFA ratio recommended is 0.45 (HMSO 1994), which was lower than those (1.50–1.86) obtained from this study. This ratio was found to be high in male cuttlefish in autumn and winter but it was slightly higher in female cuttlefish in spring.

Lipid quality indicators that depend on the relative contents of particular groups of FAs are the AI and TI, which indicate the global dietetic quality of lipids and their potential effect on the development of coronary disease (Ulbricht and Southgate 1991). In this study, AI values (0.35–0.46) were higher than TI values (0.15–0.19; Table III). It was also observed that season has an effect on the values of those indices. Higher values of AI were obtained in autumn and winter except in spring, whereas TI values remained similar in autumn and winter for both sexes.

Conclusion

The results indicate that although differences were observed in proximate composition among seasons, this species is an excellent protein source and is low in fat content regardless of sex and season. Since its muscle lipids were found to be rich in protein and PSFAs (especially EPA and DHA) for all seasons, it would be recommended as a part of diet.

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